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DTC PROJECT NO. 8-CO-160-UXO-021
REPORT NO. ATC-8768

# STANDARDIZED

# UXO TECHNOLOGY DEMONSTRATION SITE

# BLIND GRID SCORING RECORD NO. 186

SITE LOCATION:
U.S. ARMY YUMA PROVING GROUND

DEMONSTRATOR:
G-TEK AUSTRALIA PTY LIMITED
3/10 HUDSON STREET
ALBION QLD 4010 AUSTRALIA

TECHNOLOGY TYPE/PLATFORM:
TM-5 EMU (DUAL SENSOR)/MAN PORTABLE

PREPARED BY:
U.S. ARMY ABERDEEN TEST CENTER
ABERDEEN PROVING GROUND, MD 21005-5059

AUGUST 2004

Prepared for:
U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MD 21010-5401

U.S. ARMY DEVELOPMENTAL TEST COMMAND
ABERDEEN PROVING GROUND, MD 21005-5055

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**14. ABSTRACT**
This scoring record documents the efforts of U.S. Army Corps of Engineers Engineering Research and Development Center (ERDC) to detect and discriminate inert unexploded ordnance (UXO) utilizing the YPG Standardized UXO Technology Demonstration Site Blind Grid. The scoring record was coordinated by Larry Overbay and by the Standardized UXO Technology Demonstration Site Scoring Committee. Organizations on the committee include the U.S. Army Corps of Engineers, the Environmental Security Technology Certification Program, the Strategic Environmental Center, and the U.S. Army Aberdeen Test Center.

**15. SUBJECT TERMS**
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# SECTION 1. GENERAL INFORMATION

## 1.1 BACKGROUND

Technologies under development for the detection and discrimination of unexploded ordnance (UXO) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at Aberdeen Proving Ground (APG), Maryland and U.S. Army Yuma Proving Ground (YPG), Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments.

The Standardized UXO Technology Demonstration Site Program is a multi-agency program spearheaded by the U.S. Army Environmental Center (AEC). The U.S. Army Aberdeen Test Center (ATC) and the U.S. Army Corps of Engineers Engineering Research and Development Center (ERDC) provide programmatic support. The program is being funded and supported by the Environmental Security Technology Certification Program (ESTCP), the Strategic Environmental Research and Development Program (SERDP) and the Army Environmental Quality Technology Program (EQT).

## 1.2 SCORING OBJECTIVES

The objective in the Standardized UXO Technology Demonstration Site Program is to evaluate the detection and discrimination capabilities of a given technology under various field and soil conditions. Inert munitions and clutter items are positioned in various orientations and depths in the ground.

The evaluation objectives are as follows:

a. To determine detection and discrimination effectiveness under realistic scenarios that varies targets, geology, clutter, topography, and vegetation.

b. To determine cost, time, and manpower requirements to operate the technology.

c. To determine demonstrator's ability to analyze survey data in a timely manner and provide prioritized "Target Lists" with associated confidence levels.

d. To provide independent site management to enable the collection of high quality, ground-truth, geo-referenced data for post-demonstration analysis.

### 1.2.1 Scoring Methodology

a. The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection ($P_d$) and the false alarms are reported as receiver-operating

characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive ($P_{fp}$), and those that do not correspond to any known item, termed background alarms.

b. The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the blind grid RESPONSE STAGE, the demonstrator provides the scoring committee with a target response from each and every grid square along with a noise level below which target responses are deemed insufficient to warrant further investigation. This list is generated with minimal processing and, since a value is provided for every grid square, will include signals both above and below the system noise level.

c. The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such and to reject clutter. For the blind grid DISCRIMINATION STAGE, the demonstrator provides the scoring committee with the output of the algorithms applied in the discrimination-stage processing for each grid square. The values in this list are prioritized based on the demonstrator's determination that a grid square is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For digital signal processing, priority ranking is based on algorithm output. For other discrimination approaches, priority ranking is based on human (subjective) judgment. The demonstrator also specifies the threshold in the prioritized ranking that provides optimum performance, (i.e. that is expected to retain all detected ordnance and rejects the maximum amount of clutter).

d. The demonstrator is also scored on EFFICIENCY and REJECTION RATIO, which measures the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from non-ordnance items. EFFICIENCY measures the fraction of detected ordnance retained after discrimination, while the REJECTION RATIO measures the fraction of false alarms rejected. Both measures are defined relative to performance at the demonstrator-supplied level below which all responses are considered noise, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

e. All scoring factors are generated utilizing the Standardized UXO Probability and Plot Program, version 3.1.1.

### 1.2.2 Scoring Factors

Factors to be measured and evaluated as part of this demonstration include:

a. Response Stage ROC curves:

(1) Probability of Detection ($P_d^{res}$).

(2) Probability of False Positive ($P_{fp}^{res}$).

(3) Background Alarm Rate ($BAR^{res}$) or Probability of Background Alarm ($P_{BA}^{res}$).

b. Discrimination Stage ROC curves:

(1) Probability of Detection ($P_d^{disc}$).

(2) Probability of False Positive ($P_{fp}^{disc}$).

(3) Background Alarm Rate ($BAR^{disc}$) or Probability of Background Alarm ($P_{BA}^{disc}$).

c. Metrics:

(1) Efficiency (E).

(2) False Positive Rejection Rate ($R_{fp}$).

(3) Background Alarm Rejection Rate ($R_{BA}$).

d. Other:

(1) Probability of Detection by Size and Depth.

(2) Classification by type (i.e., 20-mm, 40-mm, 105-mm, etc.).

(3) Location accuracy.

(4) Equipment setup, calibration time and corresponding man-hour requirements.

(5) Survey time and corresponding man-hour requirements.

(6) Reacquisition/resurvey time and man-hour requirements (if any).

(7) Downtime due to system malfunctions and maintenance requirements.

## 1.3 STANDARD AND NONSTANDARD INERT ORDNANCE TARGETS

The standard and nonstandard ordnance items emplaced in the test areas are listed in Table 1. Standardized targets are members of a set of specific ordnance items that have identical properties to all other items in the set (caliber, configuration, size, weight, aspect ratio, material, filler, magnetic remanence, and nomenclature). Nonstandard targets are inert ordnance items having properties that differ from those in the set of standardized targets.

**TABLE 1. INERT ORDNANCE TARGETS**

| Standard Type | Nonstandard (NS) |
|---|---|
| 20-mm Projectile M55 | 20-mm Projectile M55 |
| | 20-mm Projectile M97 |
| 40-mm Grenades M385 | 40-mm Grenades M385 |
| 40-mm Projectile MKII Bodies | 40-mm Projectile M813 |
| BDU-28 Submunition | |
| BLU-26 Submunition | |
| M42 Submunition | |
| 57-mm Projectile APC M86 | |
| 60-mm Mortar M49A3 | 60-mm Mortar (JPG) |
| | 60-mm Mortar M49 |
| 2.75-inch Rocket M230 | 2.75-inch Rocket M230 |
| | 2.75-inch Rocket XM229 |
| MK 118 ROCKEYE | |
| 81-mm Mortar M374 | 81-mm Mortar (JPG) |
| | 81-mm Mortar M374 |
| 105-mm Heat Rounds M456 | |
| 105-mm Projectile M60 | 105-mm Projectile M60 |
| 155-mm Projectile M483A1 | 155-mm Projectile M483A |
| | 500-lb Bomb |
| | M75 Submunition |

JPG = Jefferson Proving Ground.

# SECTION 2. DEMONSTRATION

## 2.1 DEMONSTRATOR INFORMATION

### 2.1.1 Demonstrator Point of Contact (POC) and Address


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ALBION QLD 4010 Australia


### 2.1.2 System Description (provided by demonstrator)

a. Sensor System Description. The man portable TM-5 EMU consists of the following components:

| Item | Manufacturer | Model |
|---|---|---|
| Magnetometer Control Module | G-TEK | TM-5 EMU MPX |
| Multi-period, transient electromagnetic (EM) sensors | Minelab Electronics | F1B2 |
| DGPS (digital Global Positioning System) | Ashtech | Z-Extreme |
| Odometer | G-TEK | TM-4D |

The TM-5 EMU detector system may be configured with one or two sensors measuring the transient EM response. In the application proposed, two sensors will be mounted in an array, oriented perpendicular to the survey direction delivering a 1.2-meter swath width. In the dual-sensor mode, the TM-5 EMU is operated by a single person (fig. 1).

The TM-5 EMU interfaces with both industry standard real-time kinematic (RTK) DGPS and proprietary cotton thread based odometer systems providing versatile positioning adaptable to varied terrain and vegetation conditions. It has been successfully used for over 5 years. The odometer remains the positioning technology of choice in adverse terrains; DGPS is preferred in open environments. Combined, they meet the requirements of most situations.

The TM-5 EMU user interface provides a continuous set of data quality monitors. There are audio and graphic displays and alarms monitoring sensor signal quality and position data quality. A key attribute of the TM-5 EMU is its virtual immunity to hot rocks.

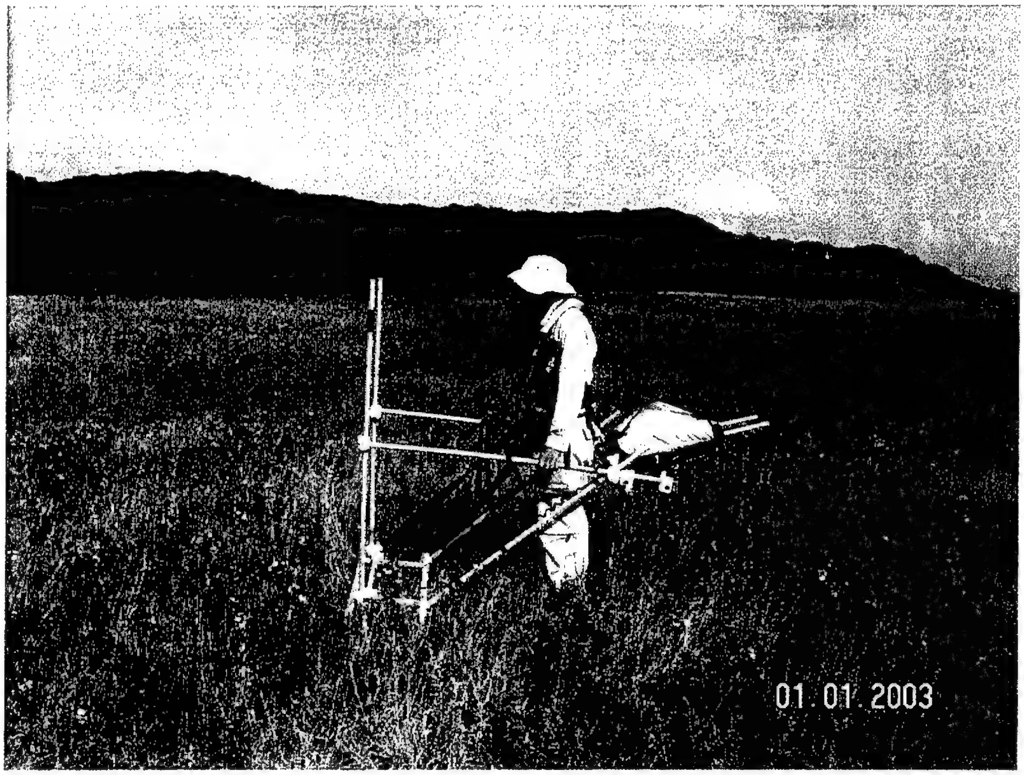


Figure 1. Demonstrator's system, TM-5 EMU (dual sensor).

Prior to performing a survey, the TM-5 EMU undergoes three procedures taking 5 minutes to complete all three. (1) Sensor pulse repetition frequency is swept over about 100 Hz, centered at 1200 Hz, to select the frequency corresponding to the lowest receiver RMS noise level, in order to minimize radio frequency (RF) interference. (2) Sensors are ground balanced to compute ground response parameters that are stored in memory so that the ground response may then be subtracted from the received signal in real-time. (3) A control source known as an EMUlator is used check that sensor signal levels are within specification.

The sensors are a monocoil acting as both transmitter and receiver, operated as a vertical magnetic dipole, with 16 turns, a diameter of 18 inches, inductance of 300 μH and resistance of 0.7 **Ω**. During surveying, the sensor coil height is maintained at an elevation of 100 mm, with the minimum HERO safe operating height calculated to be 10 cm above ground.

The transmitted waveform consists of two different length pulses (200 μs, 3.3 A and 50 μs, 830 mA), repeated at the rate of approximately 1200 Hz. The peak pulse amplitudes are based on an application of 5 V, and at turn-off, the pulses ramp to zero in about 2-4 μs, (corresponding to the self-induced EMF clipped to 187 V). The theoretical bandwidth of about 500 kHz reduces to about 300 kHz after the addition of amplifiers and integrators. The detector is based on synchronous demodulation, sampling the secondary field decays over narrow integration gates. After subtracting the ground response and digitizing at approximately 60 Hz, the output is decimated to 32 samples per second that are recorded with a DGPS position at a ≥1 Hz rate.

Amplifier gains are adjusted to provide digital output between $\pm$ 4096 units such that background noise is set to $\pm$ 1 to 2 units. A low pass filter is applied at periodic intervals to reset the background signal to a zero mean. During a traverse this filter is switched out so that the filter does not attenuate target responses, and the drift is removed from the digital record in post-processing with a high-pass filter.

b. Positioning System Description. G-TEK proposed using a combination of the following survey/navigation technologies:

| Item | Manufacturer | Model |
|---|---|---|
| DGPS | Ashtech | Z-Extreme |
| Odometer | G-TEK | TM-4D |
| Polychain | PEKO | 100M |
| Siters | Various | Generic traffic cones. Wooden dowels and flagging. |

The TM-5 EMU detector system interfaces with both industry standard RTK DGPS and proprietary cotton thread based odometer systems providing versatile time or position-based positioning that is adaptable to varied terrain and vegetation conditions. In both cases, where UXO detection standards of survey coverage are required, G-TEK operators use a pre-established control grid and visual sighters for straight-line navigation, and use the DGPS or odometer for data positioning only.

**2.1.2.1 Using DGPS in the Open Area.** DGPS is the technology of choice in situations where satellite coverage is reliable. In this case, any of the industry standard RTK systems (with the precise 1 pulse per second facility) may be used although in this program we propose using the Ashtech Z-Extreme system (with NovAtel RT-2 as a backup). The preference is to establish a Global Positioning System (GPS) base-station on a monument that is within 1 km of the survey area and to use a radio link to the roving GPS receiver. In the roving instrumentation, sensor data is merged synchronized with the transformed DGPS positions and recorded. In this way, sensor data is positioned with an accuracy of better than 5 cm. Prior to commencing survey, the roving GPS is located at a known reference to confirm the integrity of the system and transformations used. The real time DGPS will be used to establish a control grid using non-metallic pegs at intervals appropriate to the level of visibility. At APG a control line interval of 25 or 50 meters is anticipated. The non-metallic polychains will then be laid as control lines, perpendicular to the proposed survey direction. Visual sighters will be located along the first survey line and used as a visual aid to navigation. As each sighter is reached, it is moved 0.8 meters laterally to the position of the return survey line.

**2.1.2.2 Using the Odometer in the Wooded Area.** The control grid setup will combine the use of DGPS and cotton odometer survey techniques. Navigation will be done the same as described above. However, 5 meters before the commencement of each new transect, the cotton thread is tied to either vegetation or a small peg anchored to the ground. When each control line is reached, a distance mark is recorded in the TM-5 EMU prior to moving the cone. At the completion of each survey grid section the cotton is gathered and removed from the site. In

post-processing, linear error distribution delivers positional accuracy that is typically less than 0.1 percent of the distance between control lines (0.1 percent of 25 meters delivers 2.5 cm accuracy in this case.) Because the odometer is used in more adverse terrain including forests, protocols have been developed using the electronic notepad facility of the TM-5 EMU for recording the location of obstacles (eg. trees) and the direction taken around these. If a UXO is detected close to such a tree, the validation team will know which side of the tree to search. Experience over many years surveying in forested conditions has indicated that an rms target position error of less than 30 mm can be anticipated with the greatest errors occurring where obstacles are circumvented. These errors are not cumulative and are comparable with the interpreted target position errors achieved using DGPS.

### 2.1.3 <u>Data Processing Description (provided by demonstrator)</u>

a. Data Processing. The data will be processed in the following sequence (the software used at each step is noted in square brackets):

b. Data Acquisition.

(1) Up to 2 sensors of 2-channel EM data will be recorded at 32 Hz in DGPS mode and 5 cm in cotton odometer distance-mode [G-TEK's EMUDAS field Data Acquisition software].

(2) The GPS positions (at no less than 1 Hz) will be transformed in real-time into the required coordinate system [G-TEK's EMUDAS field Data Acquisition software].

(3) In cotton odometer mode the precise vertices of the survey boundary and control lines are measured with the RTK-DGPS and entered into the TM-5 EMU EM. The operator will be responsible for activating the start and stop button for each line [G-TEK's EMUDAS].

(4) The GPS and EM data will be merged on the 32 Hz time-base in real-time. Drift corrections are then applied [EMUDAS]. In distance-mode no merging is required.

(5) The data will automatically be assigned unique line-numbers during the data acquisition. The data will be indexed by these line-numbers during the line-based processing (i.e. up to the gridding stage). Extraneous data will be either automatically or manually flagged as not required.

(6) The positions of the individual sensors will be calculated from the precisely measured sensor-GPS antenna offsets and the instantaneous track direction of the array. These individual sensor track positions will be referenced as sub-lines 1 to 2. In distance-mode this stage is automated [G-TEK's EMUDAS].

(7) All data will be transferred from the field device to the processing computer and a Field Data Sheet will be completed by each crew leader (attachment A, DID OE-005-05.01).

c. Post-Processing by the Processing Geophysicist.

(1) The GPS track will be checked, edited and smoothed, as required [Geosoft]. For cotton positioning the distance recorded by the precise electronic odometer will be compared to the expected known length of each line [G-TEK's Distance-Based Processing Software].

(2) The EM data will then be automatically and manually scanned for the removal of invalid data [Geosoft].

(3) At this stage the raw data will be exported to Geosoft ASCII XYZ format (with line reference headers and column labels) complying with the raw data submittal guidelines on the Standardized UXO Technology Demonstration Site-Submission for Scoring web site. The data will then be written to compact disc (CD) for submission [Geosoft].

(4) The data will then be refiducialled to a distance-base of no greater than 0.05 meter to facilitate band-pass filtering to reduce effects with wavelengths determined to be inconsistent with the target anomalies (e.g. radio interference) [Geosoft-G-TEK's Geosoft executable (GXs)].

(5) Both channels of data will then be gridded to a square mesh no greater than 0.05 meter, using minimum curvature gridding with a maximum tension of 1 and using the Geosoft FLOAT grid format [Geosoft].

(6) Both Channels of gridded data will then be loaded into the viewing and interpretation software for semi-automated interpretation. This process involves the automatic selection of positive and negative maximums and whose amplitudes exceed the interpretation thresholds. These selections are then manually checked and amended. Parameters from the selected anomalies (from both channels) are then determined for use in an automated rule-based discrimination procedure. Use will be made of the ground-truth data from the calibration lane to fine-tune the discrimination settings. This will then provide the basis for the discrimination classification and prioritization in the submittal [G-TEK's MagSys].

(7) The information on the selected anomalies (processed data) will then be imported into a Microsoft (MS) Excel spreadsheet for formatting for presentation as a dig sheet based on the template attachment C, DID OE-005-05.01 and written to CD for submittal [G-TEK's EODReporter MS Excel macro].

(8) The dig sheet data (processed data) will also be reformatted to comply with the Processed Data Submittal guidelines on the Standardized UXO Technology Demonstration Site-Submission for Scoring web site. The data will then be written to a CD for submission [MS EXCEL].

(9) The color contour, processed EM grid-image, with selected anomalies marked will be presented based on the map template attachment D, DID OE-005-05.01 also on a CD [Geosoft].

d. Data processing during interrogation (Blind Test Grid). Anomaly parameters such as peak amplitude and width at half-amplitude in the north-south and east-west directions will be captured. These parameters will then be used in a rule based discrimination system for the discrimination classification and prioritization in the submittal [G-TEK's EODReporter].

### 2.1.4 Data Submission Format

Data were submitted for scoring in accordance with data submission protocols outlined in the Standardized UXO Technology Demonstration Site Handbook. These submitted data are not included in this report in order to protect ground truth information.

### 2.1.5 Demonstrator Quality Assurance (QA) and Quality Control (QC) (provided by demonstrator)

G-TEK will perform QC steps and tests using the DID OE-005-05.02 with the following QC test frequency:

| Test Description | Power On | Day Start | Day Start and End | First Day | Repeat Last Two Grid Lines |
|---|---|---|---|---|---|
| Equipment Warm Up | 5-min | | | | |
| Record Sensor Offsets | | X | | | |
| Personnel Test | | X | | | |
| Vibration Test | | X | | | |
| Static & Spike Test | | | 3 min/1 min/ 3 min | | |
| Six Line Test | | | | X | |
| Repeat Lines | | | | | X |
| Visit Survey Point | | | X | | |

***Equipment/Electronics Warm-up for 5 minutes:*** This allows for thermal stabilization of electronics.

***Record Relative Sensor Position (criteria: 1 cm accuracy):*** Document relative navigation and sensor offsets, detector separation, and detector heights above the ground surface.

***Personnel Test (Criteria < 10 EMU at 10 cm from sensors):*** To ensure survey personnel have removed all potential metallic interference sources from their bodies.

***Shake Test (< Criteria 10 EMU)***: To identify and repair or replace shorting cables and broken pin-outs on connectors. With the instrument held in a static position and collecting data, cables are shaken to test for shorts and broken pin outs. Repaired or replaced cables are rigorously retested before use.

***Static Background and Static Standard Response (Spike) Test (Criteria:10 EMU):*** To quantify instrument background readings, electronic drift, locate potential interference spikes, and determine impulse response and repeatability of the instrument to a standard item. Review in real-time.

***Six Line Test (Criteria: Repeatability of response amplitude ± 20 percent, positional Accuracy ± 20 cm):*** To document latency, heading effects, repeatability of response amplitude, and positional accuracy. The test line will be well marked to facilitate data collection over the exact same line each time the test is performed. Background response over the test line is established in Lines 1 and 2. A standard test item, such as a steel trailer hitch ball will be used for Lines 3 through 6.

***Visit Survey Point (Criteria: ±25 cm):*** Check that GPS base location and transformations are correct.

***Repeat Last Two Lines of Each Grid (Criteria: Repeatability of Response Amplitude ± 20 percent, Positional Accuracy ± 20 cm):*** To determine positional and geophysical data repeatability.

***TM-5~EMU Calibration (Criteria: >250 EMU):*** By the use of a calibration device known as an "EMUlator" (developed by G-TEK for the purpose of establishing the integrity of the TM-5 EMU) the EMUlator is placed touching the rim of the sensor coil and data is recorded for a period of 60 seconds. The EMUlator delivers a controlled response to the excitation transmitted by the TM-5 EMU.

***Sensor Elevation:*** The TM-5 EMU will be operated at a low but uniform elevation. To help the operator achieve this, a piece of non-conductive tape will be attached to the back of the coil such that it hangs 10 cm. The operator then maintains the end of the tape just touching the ground (or where he judges the ground to be below the grass cover). Higher elevations due to vegetation will be noted.

***Data Processing:*** a second geophysicist will check the data processing and interpretation. All intermediate processing stages of the data will be retained in meaningfully named columns within GEOSOFT for this purpose. All data will be backed up daily.

For quality assurance measures, the data collected during the pre-survey QC checks will be processed, documented and checked by the Data Processing Geophysicist to assure that the entire system will provide the quality to achieve the desired outcome of detecting and correctly discriminating the UXO items down to their specified depth as determined by the site conditions. The RTK-DGPS systems have a quoted accuracy of 2.0 cm+0.1 mm/(km to the base-station) Central Error Probability (CEP) in dynamic mode. In practice, however, assuming a consistent differential correction of 1 per second and a baseline less than 2 km the worst case absolute accuracy will be ± 5.0 cm with a typical accuracy of ± 2.5 cm. Synchronization errors between the EM detector and the GPS will be reduced by calibration down to the resolution of the sampling rate of 0.03 second. In sloping terrain there will be an additional error when the GPS antennae pole varies from the vertical.

In the forested areas we will use an electronic cotton odometer system to track the sensors' positions along line. This system has an inherent along-line accuracy of <1 percent and a resolution of 5 cm. However, when the start and end positions are known, this error is reduced to <0.2 percent of the distance between known points. In this case we propose to have control lines at not greater than 25 m intervals. That is an accuracy of ± 5 cm.

***Estimated Accuracy of the Navigation System:*** The primary navigation method will use accurately placed sighters along control lines. The operators must then keep at least two sighters in line with the center point of the sensor array. This navigation technique will be used with both the cotton and GPS position tracking systems. The advantage of system is its simplicity and applicability to difficult situations. The accuracy of this system depends on the accuracy of the pegged grid and the diligence of the operators. The anticipated typical across-line error is $\pm$10 cm. The effective swath width of the 2-sensor-array will be 1.2 m. The nominal lane spacing of 1.0 m will allow for cross-line navigation variations.

***QA of Positioning:*** The GEOSOFT DoD UXO QA System will be used to report on "Line Coverage Comparison". This report will allow the quantification of the data positioning on a line basis. Lines that fail will trigger "Re-Do" orders to Field Crew Leaders.

***QA of Sensor Data Quality:*** The quality of each sub-line of data will be quantified as the largest distance with consecutive invalid sensor data. If a sub-line fails the criteria then a "Re-Do" order will be triggered. The magnetometer base-station will be subjected to similar quality quantification and recording process.

***QA Based on a Two Traverse Resurvey:*** The sensor data and interpretation will be compared to the original and the whole-system repeatability will be reported for quality assurance.

***QA of Data Processing:*** *during data processing the software will automatically correlate the dates and times of the various data streams.* A second QC geophysicist will check the quality of the raw data, the selected processing parameters, interpretation parameters and the final gridded data. They will then provide quality assurance of the interpretation by checking each grid of data for missed anomalies. The QC geophysicist can then add but not delete more anomalies. The QC geophysicist will then repeat the discrimination process on 10 percent of the anomalies and compare the results. This process will then assure the quality of the final prioritized dig sheet result. This will then allow the generation of a quantified assured depth of detection versus calibre graph.

***QA of Reacquisition and Validation:*** After anomaly validation entry of the finds into the dig sheet (based on the template "Attachment C, DID OE-005-05.01") the dig-sheet is returned to the processing geophysicist. The Processing Geophysicist then checks the description of the finds against the interpretation. Any discrepancies would be tracked on the dig-sheet into columns provided and the validation team may be asked to reinvestigate those items not signed off by the geophysicist. The completed dig sheet will then provide a further QA product.

### 2.1.6 Additional Records

The following record(s) by this vendor can be accessed via the Internet as PDF files at www.uxotestsites.org.

## 2.2 YPG SITE INFORMATION

### 2.2.1 Location

YPG is located adjacent to the Colorado River in the Sonoran Desert. The UXO Standardized Test Site is located south of Pole Line Road and east of the Countermine Testing and Training Range. The Open Field range, Calibration Grid, Blind Grid, Mogul area, and Desert Extreme area comprise the 350- by 500-meter general test site area. The open field site is the largest of the test sites and measures approximately 200 by 350 meters. To the east of the open field range are the calibration and blind test grids that measure 30 by 40 meters and 40 by 40 meters, respectively. South of the Open Field is the 135- by 80-meter Mogul area consisting of a sequence of man-made depressions. The Desert Extreme area is located southeast of the open field site and has dimensions of 50 by 100 meters. The Desert Extreme area, covered with desert-type vegetation, is used to test the performance of different sensor platforms in a more severe desert conditions/environment.

### 2.2.2 Soil Type

Soil samples were collected at the YPG UXO Standardized Test Site by ERDC to characterize the shallow subsurface (<3 m). Both surface grab samples and continuous soil borings were acquired. The soils were subjected to several laboratory analyses, including sieve/hydrometer, water content, magnetic susceptibility, dielectric permittivity, X-ray diffraction, and visual description.

There are two soil complexes present within the site, Riverbend-Carrizo and Cristobal-Gunsight. The Riverbend-Carrizo complex is comprised of mixed stream alluvium, whereas the Cristobal-Gunsight complex is derived from fan alluvium. The Cristobal-Gunsight complex covers the majority of the site. Most of the soil samples were classified as either a sandy loam or loamy sand, with most samples containing gravel-size particles. All samples had a measured water content less than 7 percent, except for two that contained 11-percent moisture. The majority of soil samples had water content between 1 to 2 percent. Samples containing more than 3 percent were generally deeper than 1 meter.

An X-ray diffraction analysis on four soil samples indicated a basic mineralogy of quartz, calcite, mica, feldspar, magnetite, and some clay. The presence of magnetite imparted a moderate magnetic susceptibility, with volume susceptibilities generally greater than 100-by-10-5 SI.

For more details concerning the soil properties at the YPG test site, go to www.uxotestsites.org on the web to view the entire soils description report.

### 2.2.3 Test Areas

A description of the test site areas at YPG is included in Table 2.

**TABLE 2. TEST SITE AREAS**

| Area | Description |
|---|---|
| Calibration Grid | Contains the 15 standard ordnance items buried in six positions at various angles and depths to allow demonstrator equipment calibration. |
| Blind Grid | Contains 400 grid cells in a 0.16-hectare (0.39-acre) site. The center of each grid cell contains ordnance, clutter, or nothing. |

# SECTION 3. FIELD DATA

## 3.1 DATE OF FIELD ACTIVITIES: 28 October 2003

## 3.2 AREAS TESTED/NUMBER OF HOURS

Areas tested and total number of hours operated at each site is summarized in Table 3.

TABLE 3. AREAS TESTED AND NUMBER OF HOURS

| Area | Number of Hours |
|---|---|
| Calibration Lanes | 1.25 |
| Blind Grid | 1.17 |

## 3.3 TEST CONDITIONS

### 3.3.1 Weather Conditions

A YPG weather station located approximately one mile west of the test site was used to record average temperature and precipitation on a half hour basis for each day of operation. The temperatures listed in Table 4 represent the average temperature during field operations from 0700 to 1700 hours while precipitation data represents a daily total amount of rainfall. Hourly weather logs used to generate this summary are provided in Appendix B.

TABLE 4. TEMPERATURE/PRECIPITATION DATA SUMMARY

| Date, 2003 | Average Temperature, °F | Total Daily Precipitation, in. |
|---|---|---|
| 28 October | 73.65 | 0.00 |

### 3.3.2 Field Conditions

The field conditions remained dry throughout the demonstration.

### 3.3.3 Soil Moisture

Three soil probes were placed at various locations within the site to capture soil moisture data: Calibration, Mogul, and Desert Extreme areas. Measurements were collected in percent moisture and were taken twice daily (morning and afternoon) from five different soil depths (1 to 6 in., 6 to 12 in., 12 to 24 in., 24 to 36 in., and 36 to 48 in.) from each probe. Soil moisture logs are included in Appendix C.

## 3.4 FIELD ACTIVITIES

### 3.4.1 Setup/Mobilization

These activities included initial mobilization and daily equipment preparation and break down. Initial set up of equipment took 1 hour and 40 minutes on 28 October 2003. Total survey was conducted within one day and G-TEK went on to the Open Field for the remainder of the day. Therefore, there was no time accounted for daily set up or breakdown time.

### 3.4.2 Calibration

G-TEK spent 1 hour and 15 minutes in the Calibration Lanes after completing the Blind Grid survey on 28 October 2003.

### 3.4.3 Downtime Occasions

Occasions of downtime are grouped into five categories: equipment/data checks or equipment maintenance, equipment failure and repair, weather, Demonstration Site issues, or breaks/lunch. All downtime is included for the purposes of calculating labor costs (section 5) except for downtime due to Demonstration Site issues. Demonstration Site issues, while noted in the Daily Log, are considered non-chargeable downtime for the purposes of calculating labor costs and are not discussed. Breaks and lunches are not discussed either.

**3.4.3.1 Equipment/data checks, maintenance.** G-TEK spent 13 minutes downloading data while surveying the Blind Grid. A total of 23 minutes was spent in the calibration on swapping out a battery, downloading data and waiting on a GPS lock.

**3.4.3.2 Equipment failure or repair.** G-TEK experienced no equipment failures while utilizing the TM 5 EMU in the calibration Lanes and Blind Grid.

**3.4.3.3 Weather.** Overall weather conditions did not interfere with the demonstration. Conditions remained dry and pleasant.

### 3.4.4 Data Collection

G-TEK spent 57 minutes collecting data in the Blind Grid. This time excludes break/lunches and downtimes described in paragraph 3.4.3.

### 3.4.5 Demobilization

G-TEK went on to conduct a demonstration of the entire site. Therefore, demobilization did not occur until 6 November 2003. On that day, it took the crew spent 1 hour and 17 minutes to break down and pack up their equipment.

## 3.5 PROCESSING TIME

G-TEK submitted the raw data from the demonstration activities on the last day of the demonstration, as required. The scoring submittal data was also provided within the required 30-day timeframe.

## 3.6 DEMONSTRATOR'S FIELD PERSONNEL

Mr. Peter Clark, Site Manager
Mr. Paul O'Donnell, Geophysicist
Mr. Bruce Symans, Crew Leader
Mr. Graham Browne, Field Technician
Mr. Terry Foot, Data Acquisition, Grid Setup

## 3.7 DEMONSTRATOR'S FIELD SURVEYING METHOD

G-TEK began surveying in the northwest corner of both the calibration and blind grids. Both surveys were conducted in a north to south direction.

## 3.8 SUMMARY OF DAILY LOGS

Daily logs capture all field activities during this demonstration and are located in Appendix D. Activities pertinent to this specific demonstration are indicated in highlighted text.

No significant activities occurred while surveying the Blind Grid.

## SECTION 4. TECHNICAL PERFORMANCE RESULTS

### 4.1 ROC CURVES USING ALL ORDNANCE CATEGORIES

Figure 2 shows the probability of detection for the response stage ($P_d^{res}$) and the discrimination stage ($P_d^{disc}$) versus their respective probability of false positive. Figure 3 shows both probabilities plotted against their respective probability of background alarm. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

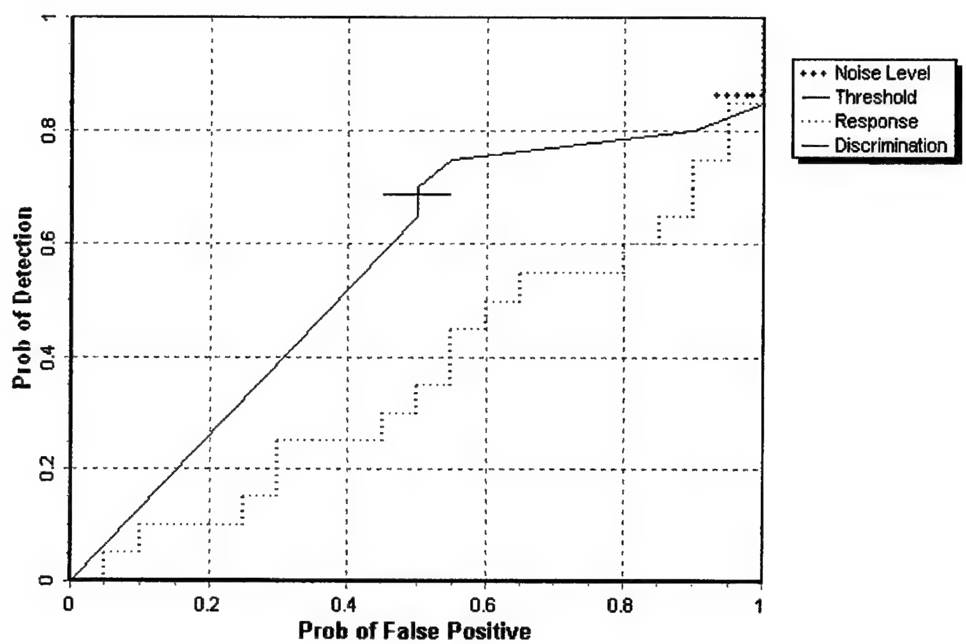


Figure 2. TM-5 EMU (dual sensor) blind grid probability of detection for response and discrimination stages versus their respective probability of false positive over all ordnance categories combined.

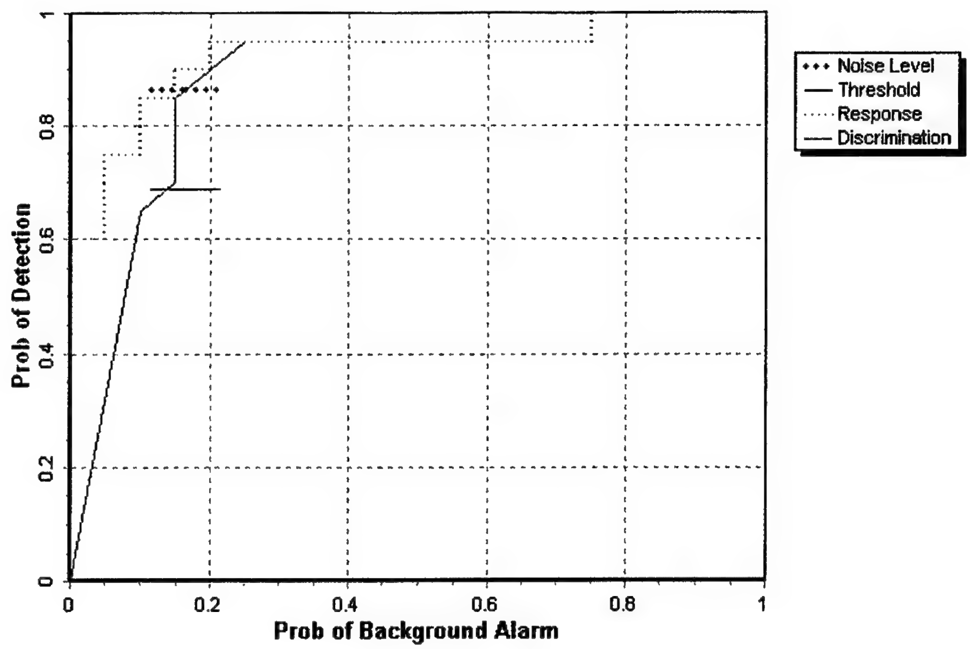


Figure 3. TM-5 EMU (dual sensor) blind grid probability of detection for response and discrimination stages versus their respective probability of background alarm over all ordnance categories combined.

## 4.2 ROC CURVES USING ORDNANCE LARGER THAN 20 MM

Figure 4 shows the probability of detection for the response stage ($P_d^{res}$) and the discrimination stage ($P_d^{disc}$) versus their respective probability of false positive when only targets larger than 20 mm are scored. Figure 5 shows both probabilities plotted against their respective probability of background alarm. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the ground truth.

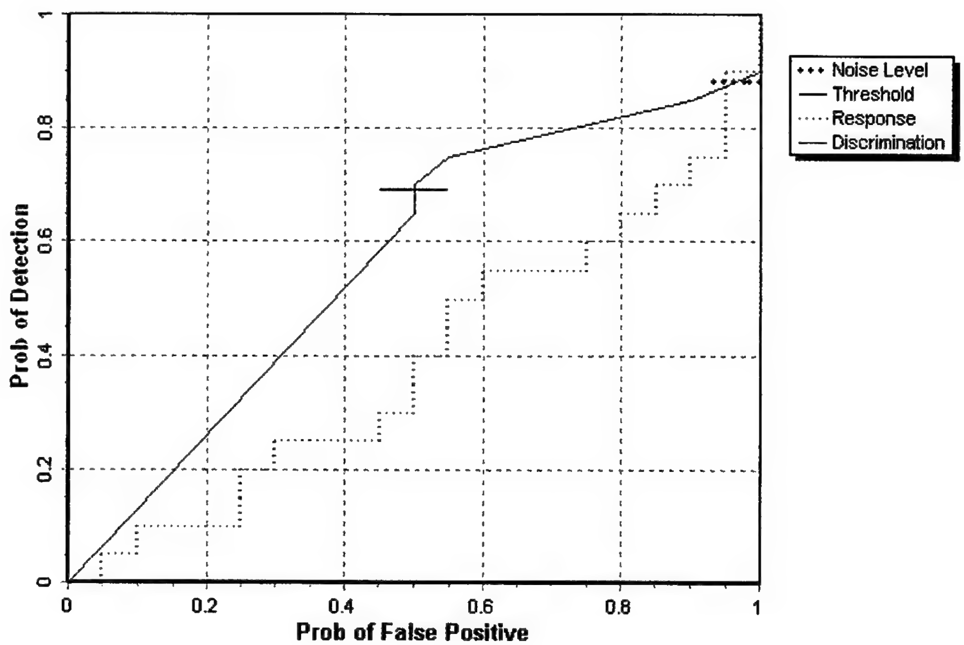


Figure 4. TM-5 EMU (dual sensor) blind grid probability of detection for response and discrimination stages versus their respective probability of false positive for all ordnance larger than 20-mm.

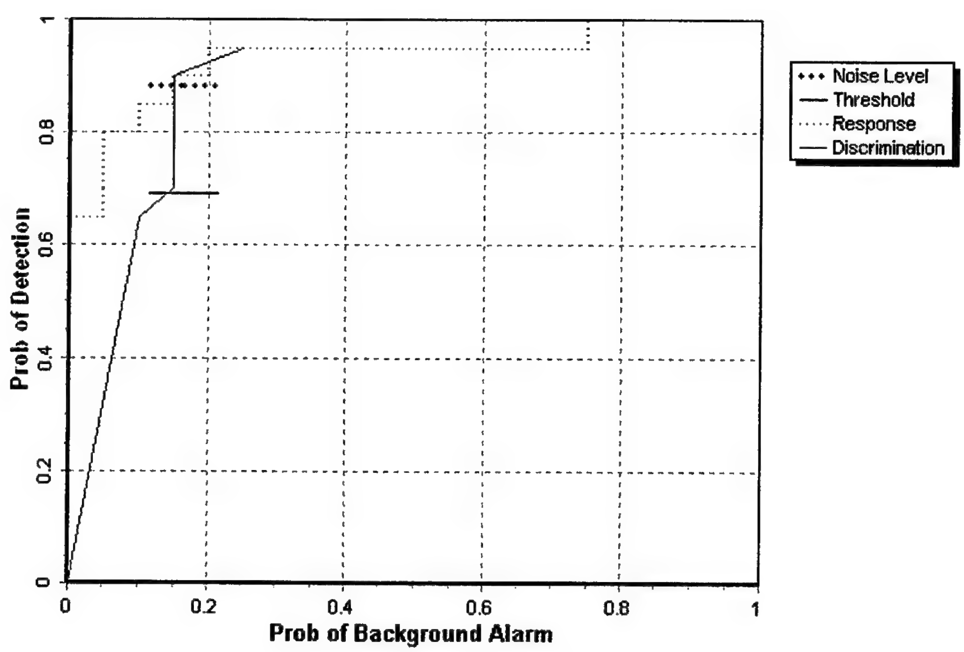


Figure 5. TM-5 EMU (dual sensor) blind grid probability of detection for response and discrimination stages versus their respective probabilities of background alarm for all ordnance larger than 20-mm.

## 4.3 PERFORMANCE SUMMARIES

Results for the Blind Grid test, broken out by size, depth and nonstandard ordnance, are presented in Table 5. (For cost results, see section 5.) Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the demonstrator did at detecting/discriminating ordnance of a certain caliber range. (See Appendix A for size definitions.) The results are relative to the number of ordnances emplaced. Depth is measured from the closest point of anomaly to the ground surface.

The RESPONSE STAGE results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the DISCRIMINATION STAGE are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90-percent confidence limit on probability of detection and probability of false positive was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results in Table 5 have been rounded to protect the ground truth. However, lower confidence limits were calculated using actual results.

**TABLE 5. SUMMARY OF BLIND GRID RESULTS FOR TM 5 EMU (DUAL SENSOR)**

| Metric | Overall | Standard | Nonstandard | By Size | | | By Depth, m | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Small | Medium | Large | < 0.3 | 0.3 to <1 | >= 1 |
| **RESPONSE STAGE** | | | | | | | | | |
| $P_d$ | 0.85 | 0.85 | 0.85 | 0.90 | 0.80 | 0.95 | 0.95 | 0.85 | 0.45 |
| $P_d$ Low 90% Conf | 0.80 | 0.78 | 0.74 | 0.80 | 0.63 | 0.75 | 0.88 | 0.69 | 0.17 |
| $P_{fp}$ | 1.00 | - | - | - | - | - | 1.00 | 1.00 | 0.00 |
| $P_{fp}$ Low 90% Conf | 0.95 | - | - | - | - | - | 0.94 | 0.92 | - |
| $P_{ba}$ | 0.15 | - | - | - | - | - | - | - | - |
| **DISCRIMINATION STAGE** | | | | | | | | | |
| $P_d$ | 0.70 | 0.65 | 0.75 | 0.85 | 0.50 | 0.55 | 0.70 | 0.70 | 0.45 |
| $P_d$ Low 90% Conf | 0.61 | 0.54 | 0.63 | 0.73 | 0.37 | 0.37 | 0.61 | 0.56 | 0.17 |
| $P_{fp}$ | 0.50 | - | - | - | - | - | 0.35 | 0.95 | 0.00 |
| $P_{fp}$ Low 90% Conf | 0.44 | - | - | - | - | - | 0.29 | 0.82 | - |
| $P_{ba}$ | 0.15 | - | - | - | - | - | - | - | - |

Response Stage Noise Level: 11.00
Recommended Discrimination Stage Threshold: 0.49

Notes: The response stage noise level and recommended discrimination stage threshold values are provided by the demonstrator.

## 4.4 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION

Efficiency and rejection rates are calculated to quantify the discrimination ability at specific points of interest on the ROC curve: (1) at the point where no decrease in $P_d$ is suffered (i.e., the efficiency is by definition equal to one) and (2) at the operator selected threshold. These values are reported in Table 6.

**TABLE 6. EFFICIENCY AND REJECTION RATES**

| | Efficiency (E) | False Positive Rejection Rate | Background Alarm Rejection Rate |
|---|---|---|---|
| At Operating Point | 0.80 | 0.49 | 0.00 |
| With No Loss of $P_d$ | 1.00 | 0.00 | 0.00 |

At the demonstrator's recommended setting, the ordnance items that were detected and correctly discriminated were further scored on whether their correct type could be identified (table 8). Correct type examples include "20-mm projectile, 105-mm HEAT Projectile, and 2.75-inch Rocket". A list of the standard type declaration required for each ordnance item was provided to demonstrators prior to testing. For example, the standard type for the three example items are: 20mmP, 105H, and 2.75in, respectively.

**TABLE 7. CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS UXO**

| Size | % Correct |
|---|---|
| Small | 16.1 |
| Medium | 0.0 |
| Large | 0.0 |
| Overall | 9.8 |

## 4.5 LOCATION ACCURACY

The mean location error and standard deviations appear in Table 8. These calculations are based on average missed depth for ordnance correctly identified in the discrimination stage. Depths are measured from the closest point of the ordnance to the surface. For the Blind Grid, only depth errors are calculated, since (x, y) positions are known to be the centers of each grid square.

**TABLE 8. MEAN LOCATION ERROR AND STANDARD DEVIATION (M)**

| | Mean | Standard Deviation |
|---|---|---|
| Depth | -0.35 | 0.30 |

## SECTION 5. ON-SITE LABOR COSTS

A standardized estimate for labor costs associated with this effort was calculated as follows: the first person at the test site was designated "supervisor", the second person was designated "data analyst", and the third and following personnel were considered "field support". Standardized hourly labor rates were charged by title: supervisor at $95.00/hour, data analyst at $57.00/hour, and field support at $28.50/hour.

Government representatives monitored on-site activity. All on-site activities were grouped into one of ten categories: initial setup/mobilization, daily setup/stop, calibration, collecting data, downtime due to break/lunch, downtime due to equipment failure, downtime due to equipment/data checks or maintenance, downtime due to weather, downtime due to demonstration site issue, or demobilization. See Appendix D for the daily activity log. See section 3.4 for a summary of field activities.

The standardized cost estimate associated with the labor needed to perform the field activities is presented in Table 9. Note that calibration time includes time spent in the Calibration Lanes as well as field calibrations. "Site survey time" includes daily setup/stop time, collecting data, breaks/lunch, downtime due to equipment/data checks or maintenance, downtime due to failure, and downtime due to weather.

**TABLE 9. ON-SITE LABOR COSTS**

| | No. People | Hourly Wage | Hours | Cost |
|---|---|---|---|---|
| **Initial Setup** | | | | |
| Supervisor | 1 | $95.00 | 1.67 | 158.65 |
| Data Analyst | 1 | 57.00 | 1.67 | 95.19 |
| Field Support | 0 | 28.50 | 1.67 | 0.00 |
| SubTotal | | | | **$253.84** |
| **Calibration** | | | | |
| Supervisor | 1 | $95.00 | 1.25 | 118.75 |
| Data Analyst | 1 | 57.00 | 1.25 | 71.25 |
| Field Support | 0 | 28.50 | 1.25 | 0.00 |
| SubTotal | | | | **$190.00** |
| **Site Survey** | | | | |
| Supervisor | 1 | $95.00 | 1.17 | 111.15 |
| Data Analyst | 1 | 57.00 | 1.17 | 66.69 |
| Field Support | 0 | 28.50 | 1.17 | 0.00 |
| SubTotal | | | | **$177.84** |

See notes at end of table.

TABLE 9 (CONT'D)

| | No. People | Hourly Wage | Hours | Cost |
|---|---|---|---|---|
| **Demobilization** | | | | |
| Supervisor | 1 | $95.00 | 1.28 | 121.60 |
| Data Analyst | 1 | 57.00 | 1.28 | 72.96 |
| Field Support | 0 | 28.50 | 1.28 | 0.00 |
| Subtotal | | | | **$194.56** |
| Total | | | | **$816.24** |

Notes: Calibration time includes time spent in the Calibration Lanes as well as calibration before each data run.
Site Survey time includes daily setup/stop time, collecting data, breaks/lunch, downtime due to system maintenance, failure, and weather.

## SECTION 6. COMPARISON OF RESULTS TO DATE

No comparisons to date.



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## SECTION 7. APPENDIXES

### APPENDIX A. TERMS AND DEFINITIONS

GENERAL DEFINITIONS

Anomaly: Location of a system response deemed to warrant further investigation by the demonstrator for consideration as an emplaced ordnance item.

Detection: An anomaly location that is within $R_{halo}$ of an emplaced ordnance item.

Emplaced Ordnance: An ordnance item buried by the government at a specified location in the test site.

Emplaced Clutter: A clutter item (i.e., non-ordnance item) buried by the government at a specified location in the test site.

$R_{halo}$: A pre-determined radius about the periphery of an emplaced item (clutter or ordnance) within which a location identified by the demonstrator as being of interest is considered to be a response from that item. If multiple declarations lie within $R_{halo}$ of any item (clutter or ordnance), the declaration with the highest signal output within the $R_{halo}$ will be utilized. For the purpose of this program, a circular halo 0.5 meters in radius will be placed around the center of the object for all clutter and ordnance items less than 0.6 meters in length. When ordnance items are longer than 0.6 meters, the halo becomes an ellipse where the minor axis remains 1 meter and the major axis is equal to the length of the ordnance plus 1 meter.

Small Ordnance: Caliber of ordnance less than or equal to 40 mm (includes 20-mm projectile, 40-mm projectile, submunitions BLU-26, BLU-63, and M42).

Medium Ordnance: Caliber of ordnance greater than 40 mm and less than or equal to 81 mm (includes 57-mm projectile, 60-mm mortar, 2.75 in. Rocket, MK118 Rockeye, 81-mm mortar).

Large Ordnance: Caliber of ordnance greater than 81 mm (includes 105-mm HEAT, 105-mm projectile, 155-mm projectile, 500-pound bomb).

Shallow: Items buried less than 0.3 meter below ground surface.

Medium: Items buried greater than or equal to 0.3 meter and less than 1 meter below ground surface.

Deep: Items buried greater than or equal to 1 meter below ground surface.

Response Stage Noise Level: The level that represents the point below which anomalies are not considered detectable. Demonstrators are required to provide the recommended noise level for the Blind Grid test area.

Discrimination Stage Threshold: The demonstrator selected threshold level that they believe provides optimum performance of the system by retaining all detectable ordnance and rejecting the maximum amount of clutter. This level defines the subset of anomalies the demonstrator would recommend digging based on discrimination.

Binomially Distributed Random Variable: A random variable of the type which has only two possible outcomes, say success and failure, is repeated for n independent trials with the probability p of success and the probability 1-p of failure being the same for each trial. The number of successes x observed in the n trials is an estimate of p and is considered to be a binomially distributed random variable.

RESPONSE AND DISCRIMINATION STAGE DATA

The scoring of the demonstrator's performance is conducted in two stages. These two stages are termed the RESPONSE STAGE and DISCRIMINATION STAGE. For both stages, the probability of detection ($P_d$) and the false alarms are reported as receiver-operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of false positive ($P_{fp}$) and those that do not correspond to any known item, termed background alarms.

The RESPONSE STAGE scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. For the RESPONSE STAGE, the demonstrator provides the scoring committee with the location and signal strength of all anomalies that the demonstrator has deemed sufficient to warrant further investigation and/or processing as potential emplaced ordnance items. This list is generated with minimal processing (e.g., this list will include all signals above the system noise threshold). As such, it represents the most inclusive list of anomalies.

The DISCRIMINATION STAGE evaluates the demonstrator's ability to correctly identify ordnance as such, and to reject clutter. For the same locations as in the RESPONSE STAGE anomaly list, the DISCRIMINATION STAGE list contains the output of the algorithms applied in the discrimination-stage processing. This list is prioritized based on the demonstrator's determination that an anomaly location is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For electronic signal processing, priority ranking is based on algorithm output. For other systems, priority ranking is based on human judgment. The demonstrator also selects the threshold that the demonstrator believes will provide "optimum" system performance, (i.e., that retains all the detected ordnance and rejects the maximum amount of clutter).

Note: The two lists provided by the demonstrator contain identical numbers of potential target locations. They differ only in the priority ranking of the declarations.

RESPONSE STAGE DEFINITIONS

Response Stage Probability of Detection ($P_d^{res}$): $P_d^{res}$ = (No. of response-stage detections)/(No. of emplaced ordnance in the test site).

Response Stage False Positive ($fp^{res}$): An anomaly location that is within $R_{halo}$ of an emplaced clutter item.

Response Stage Probability of False Positive ($P_{fp}^{res}$): $P_{fp}^{res}$ = (No. of response-stage false positives)/(No. of emplaced clutter items).

Response Stage Background Alarm ($ba^{res}$): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside $R_{halo}$ of any emplaced ordnance or emplaced clutter item.

Response Stage Probability of Background Alarm ($P_{ba}^{res}$): Blind Grid only: $P_{ba}^{res}$ = (No. of response-stage background alarms)/(No. of empty grid locations).

Response Stage Background Alarm Rate ($BAR^{res}$): Open Field only: $BAR^{res}$ = (No. of response-stage background alarms)/(arbitrary constant).

Note that the quantities $P_d^{res}$, $P_{fp}^{res}$, $P_{ba}^{res}$, and $BAR^{res}$ are functions of $t^{res}$, the threshold applied to the response-stage signal strength. These quantities can therefore be written as $P_d^{res}(t^{res})$, $P_{fp}^{res}(t^{res})$, $P_{ba}^{res}(t^{res})$, and $BAR^{res}(t^{res})$.

DISCRIMINATION STAGE DEFINITIONS

Discrimination: The application of a signal processing algorithm or human judgment to response-stage data that discriminates ordnance from clutter. Discrimination should identify anomalies that the demonstrator has high confidence correspond to ordnance, as well as those that the demonstrator has high confidence correspond to non-ordnance or background returns. The former should be ranked with highest priority and the latter with lowest.

Discrimination Stage Probability of Detection ($P_d^{disc}$): $P_d^{disc}$ = (No. of discrimination-stage detections)/(No. of emplaced ordnance in the test site).

Discrimination Stage False Positive ($fp^{disc}$): An anomaly location that is within $R_{halo}$ of an emplaced clutter item.

Discrimination Stage Probability of False Positive ($P_{fp}^{disc}$): $P_{fp}^{disc}$ = (No. of discrimination stage false positives)/(No. of emplaced clutter items).

Discrimination Stage Background Alarm ($ba^{disc}$): An anomaly in a blind grid cell that contains neither emplaced ordnance nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside $R_{halo}$ of any emplaced ordnance or emplaced clutter item.

Discrimination Stage Probability of Background Alarm ($P_{ba}^{disc}$): $P_{ba}^{disc}$ = (No. of discrimination-stage background alarms)/(No. of empty grid locations).

Discrimination Stage Background Alarm Rate ($BAR^{disc}$): $BAR^{disc}$ = (No. of discrimination-stage background alarms)/(arbitrary constant).

Note that the quantities $P_d^{disc}$, $P_{fp}^{disc}$, $P_{ba}^{disc}$, and $BAR^{disc}$ are functions of $t^{disc}$, the threshold applied to the discrimination-stage signal strength. These quantities can therefore be written as $P_d^{disc}(t^{disc})$, $P_{fp}^{disc}(t^{disc})$, $P_{ba}^{disc}(t^{disc})$, and $BAR^{disc}(t^{disc})$.

RECEIVER-OPERATING CHARACERISTIC (ROC) CURVES

ROC curves at both the response and discrimination stages can be constructed based on the above definitions. The ROC curves plot the relationship between $P_d$ versus $P_{fp}$ and $P_d$ versus BAR or $P_{ba}$ as the threshold applied to the signal strength is varied from its minimum ($t_{min}$) to its maximum ($t_{max}$) value.[1] Figure A-1 shows how $P_d$ versus $P_{fp}$ and $P_d$ versus BAR are combined into ROC curves. Note that the "res" and "disc" superscripts have been suppressed from all the variables for clarity.

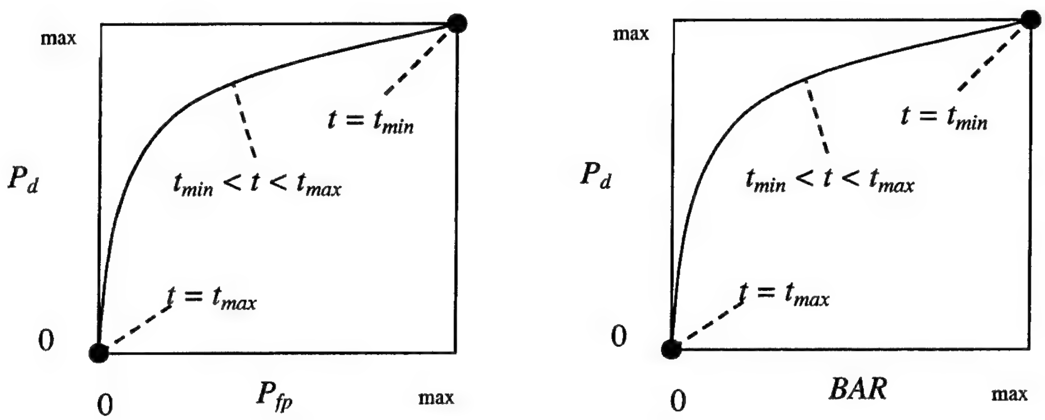


Figure A-1. ROC curves for open field-testing. Each curve applies to both the response and discrimination stages.

[1]Strictly speaking, ROC curves plot the $P_d$ versus $P_{ba}$ over a pre-determined and fixed number of detection opportunities (some of the opportunities are located over ordnance and others are located over clutter or blank spots). In an open field scenario, each system suppresses its signal strength reports until some bare-minimum signal response is received by the system. Consequently, the open field ROC curves do not have information from low signal-output locations, and, furthermore, different contractors report their signals over a different set of locations on the ground. These ROC curves are thus not true to the strict definition of ROC curves as defined in textbooks on detection theory. Note, however, that the ROC curves obtained in the Blind Grid test sites are true ROC curves.

METRICS TO CHARACTERIZE THE DISCRIMINATION STAGE

The demonstrator is also scored on efficiency and rejection ratio, which measure the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of ordnance detections from the anomaly list, while rejecting the maximum number of anomalies arising from non-ordnance items. The efficiency measures the amount of detected ordnance retained by the discrimination, while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the entire response list, i.e., the maximum ordnance detectable by the sensor and its accompanying false positive rate or background alarm rate.

Efficiency (E): $E = P_d^{disc}(t^{disc})/P_d^{res}(t_{min}^{res})$; Measures (at a threshold of interest), the degree to which the maximum theoretical detection performance of the sensor system (as determined by the response stage tmin) is preserved after application of discrimination techniques. Efficiency is a number between 0 and 1. An efficiency of 1 implies that all of the ordnance initially detected in the response stage was retained at the specified threshold in the discrimination stage, $t^{disc}$.

False Positive Rejection Rate ($R_{fp}$): $R_{fp} = 1 - [P_{fp}^{disc}(t^{disc})/P_{fp}^{res}(t_{min}^{res})]$; Measures (at a threshold of interest), the degree to which the sensor system's false positive performance is improved over the maximum false positive performance (as determined by the response stage $t_{min}$). The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all emplaced clutter initially detected in the response stage were correctly rejected at the specified threshold in the discrimination stage.

Background Alarm Rejection Rate ($R_{ba}$):

Blind Grid: $R_{ba} = 1 - [P_{ba}^{disc}(t^{disc})/P_{ba}^{res}(t_{min}^{res})]$.
Open Field: $R_{ba} = 1 - [BAR^{disc}(t^{disc})/BAR^{res}(t_{min}^{res})]$).

Measures the degree to which the discrimination stage correctly rejects background alarms initially detected in the response stage. The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all background alarms initially detected in the response stage were rejected at the specified threshold in the discrimination stage.

CHI-SQUARE COMPARISON EXPLANATION:

The Chi-square test for differences in probabilities (or 2 x 2 contingency table) is used to analyze two samples drawn from two different populations to see if both populations have the same or different proportions of elements in a certain category. More specifically, two random samples are drawn, one from each population, to test the null hypothesis that the probability of event A (some specified event) is the same for both populations (ref 4).

A 2 x 2 contingency table is used in the Standardized UXO Technology Demonstration Site Program to determine if there is reason to believe that the proportion of ordnance correctly detected/discriminated by demonstrator X's system is significantly degraded by the more challenging terrain feature introduced. The test statistic of the 2 x 2 contingency table is the

Chi-square distribution with one degree of freedom. Since an association between the more challenging terrain feature and relatively degraded performance is sought, a one-sided test is performed. A significance level of 0.05 is chosen which sets a critical decision limit of 2.71 from the Chi-square distribution with one degree of freedom. It is a critical decision limit because if the test statistic calculated from the data exceeds this value, the two proportions tested will be considered significantly different. If the test statistic calculated from the data is less than this value, the two proportions tested will be considered not significantly different.

An exception must be applied when either a 0 or 100 percent success rate occurs in the sample data. The Chi-square test cannot be used in these instances. Instead, Fischer's test is used and the critical decision limit for one-sided tests is the chosen significance level, which in this case is 0.05. With Fischer's test, if the test statistic is less than the critical value, the proportions are considered to be significantly different.

Standardized UXO Technology Demonstration Site examples, where blind grid results are compared to those from the open field and open field results are compared to those from one of the scenarios, follow. It should be noted that a significant result does not prove a cause and effect relationship exists between the two populations of interest; however, it does serve as a tool to indicate that one data set has experienced a degradation in system performance at a large enough level than can be accounted for merely by chance or random variation. Note also that a result that is not significant indicates that there is not enough evidence to declare that anything more than chance or random variation within the same population is at work between the two data sets being compared.

Demonstrator X achieves the following overall results after surveying each of the three progressively more difficult areas using the same system (results indicate the number of ordnance detected divided by the number of ordnance emplaced):

| | Blind Grid | Open Field | Moguls |
|---|---|---|---|
| $P_d^{res}$ | 100/100 = 1.0 | 8/10 = .80 | 20/33 = .61 |
| $P_d^{disc}$ | 80/100 = 0.80 | 6/10 = .60 | 8/33 = .24 |

$P_d^{res}$: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the response stage, all 100 ordnance out of 100 emplaced ordnance items were detected in the blind grid while 8 ordnance out of 10 emplaced were detected in the open field. Fischer's test must be used since a 100 percent success rate occurs in the data. Fischer's test uses the four input values to calculate a test statistic of 0.0075 that is compared against the critical value of 0.05. Since the test statistic is less than the critical value, the smaller response stage detection rate (0.80) is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the detection ability of demonstrator X's system seems to have been degraded in the open field relative to results from the blind grid using the same system.

$P_d^{disc}$: BLIND GRID versus OPEN FIELD. Using the example data above to compare probabilities of detection in the discrimination stage, 80 out of 100 emplaced ordnance items were correctly discriminated as ordnance in blind grid testing while 6 ordnance out of

10 emplaced were correctly discriminated as such in open field-testing. Those four values are used to calculate a test statistic of 1.12. Since the test statistic is less than the critical value of 2.71, the two discrimination stage detection rates are considered to be not significantly different at the 0.05 level of significance.

$P_d^{res}$: OPEN FIELD versus MOGULS. Using the example data above to compare probabilities of detection in the response stage, 8 out of 10 and 20 out of 33 are used to calculate a test statistic of 0.56. Since the test statistic is less than the critical value of 2.71, the two response stage detection rates are considered to be not significantly different at the 0.05 level of significance.

$P_d^{disc}$: OPEN FIELD versus MOGULS. Using the example data above to compare probabilities of detection in the discrimination stage, 6 out of 10 and 8 out of 33 are used to calculate a test statistic of 2.98. Since the test statistic is greater than the critical value of 2.71, the smaller discrimination stage detection rate is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause and effect relationship exists between the change in survey area and degradation in performance, it does indicate that the ability of demonstrator X to correctly discriminate seems to have been degraded by the mogul terrain relative to results from the flat open field using the same system.

# APPENDIX B. DAILY WEATHER LOGS

## TABLE B-1. WEATHER LOG

| Date | Time HH:MM | Temperature °F | R/H % | Total Precipitation (in.) |
|---|---|---|---|---|
| 2003-10-28 | 1:00 | 65.46 | 14 | 0.00 |
| 2003-10-28 | 2:00 | 65.64 | 15 | 0.00 |
| 2003-10-28 | 3:00 | 62.76 | 16 | 0.00 |
| 2003-10-28 | 4:00 | 61.83 | 17 | 0.00 |
| 2003-10-28 | 5:00 | 62.01 | 18 | 0.00 |
| 2003-10-28 | 6:00 | 59.86 | 19 | 0.00 |
| 2003-10-28 | 7:00 | 60.35 | 20 | 0.00 |
| 2003-10-28 | 8:00 | 63.12 | 20 | 0.00 |
| 2003-10-28 | 9:00 | 71.33 | 15 | 0.00 |
| 2003-10-28 | 10:00 | 78.94 | 13 | 0.00 |
| 2003-10-28 | 11:00 | 82.76 | 12 | 0.00 |
| 2003-10-28 | 12:00 | 86.43 | 11 | 0.00 |
| 2003-10-28 | 13:00 | 89.37 | 10 | 0.00 |
| 2003-10-28 | 14:00 | 91.02 | 10 | 0.00 |
| 2003-10-28 | 15:00 | 93.04 | 9 | 0.00 |
| 2003-10-28 | 16:00 | 93.78 | 9 | 0.00 |
| 2003-10-28 | 17:00 | 92.84 | 10 | 0.00 |
| 2003-10-28 | 18:00 | 88.97 | 12 | 0.00 |
| 2003-10-28 | 19:00 | 84.58 | 13 | 0.00 |
| 2003-10-28 | 20:00 | 82.54 | 13 | 0.00 |
| 2003-10-28 | 21:00 | 77.09 | 14 | 0.00 |
| 2003-10-28 | 22:00 | 75.78 | 15 | 0.00 |
| 2003-10-28 | 23:00 | 71.92 | 24 | 0.00 |
| 2003-10-28 | 24:00 | 69.57 | 23 | 0.00 |
| 2003-10-29 | 1:00 | 70.23 | 27 | 0.00 |
| 2003-10-29 | 2:00 | 69.30 | 29 | 0.00 |
| 2003-10-29 | 3:00 | 68.20 | 34 | 0.00 |
| 2003-10-29 | 4:00 | 67.23 | 36 | 0.00 |
| 2003-10-29 | 5:00 | 67.01 | 38 | 0.00 |
| 2003-10-29 | 6:00 | 65.46 | 42 | 0.00 |
| 2003-10-29 | 7:00 | 68.27 | 47 | 0.00 |
| 2003-10-29 | 8:00 | 67.60 | 55 | 0.00 |
| 2003-10-29 | 9:00 | 70.36 | 46 | 0.00 |
| 2003-10-29 | 10:00 | 72.52 | 39 | 0.00 |
| 2003-10-29 | 11:00 | 76.87 | 36 | 0.00 |
| 2003-10-29 | 12:00 | 82.27 | 39 | 0.00 |

## TABLE B-1 (CONT'D)

| Date | Time HH:MM | Temperature °F | R/H % | Total Precipitation (in.) |
|---|---|---|---|---|
| 2003-10-29 | 13:00 | 84.42 | 33 | 0.00 |
| 2003-10-29 | 14:00 | 87.82 | 26 | 0.00 |
| 2003-10-29 | 15:00 | 88.50 | 24 | 0.00 |
| 2003-10-29 | 16:00 | 88.83 | 21 | 0.00 |
| 2003-10-29 | 17:00 | 88.38 | 26 | 0.00 |
| 2003-10-29 | 18:00 | 86.09 | 29 | 0.00 |
| 2003-10-29 | 19:00 | 82.92 | 34 | 0.00 |
| 2003-10-29 | 20:00 | 79.86 | 37 | 0.00 |
| 2003-10-29 | 21:00 | 77.20 | 41 | 0.00 |
| 2003-10-29 | 22:00 | 74.68 | 48 | 0.00 |
| 2003-10-29 | 23:00 | 72.09 | 50 | 0.00 |
| 2003-10-29 | 24:00 | 69.93 | 53 | 0.00 |
| 2003-10-30 | 1:00 | 68.38 | 63 | 0.00 |
| 2003-10-30 | 2:00 | 68.04 | 69 | 0.00 |
| 2003-10-30 | 3:00 | 66.49 | 72 | 0.00 |
| 2003-10-30 | 4:00 | 64.63 | 72 | 0.00 |
| 2003-10-30 | 5:00 | 63.55 | 74 | 0.00 |
| 2003-10-30 | 6:00 | 64.63 | 77 | 0.00 |
| 2003-10-30 | 7:00 | 64.74 | 78 | 0.00 |
| 2003-10-30 | 8:00 | 64.08 | 79 | 0.00 |
| 2003-10-30 | 9:00 | 70.36 | 55 | 0.00 |
| 2003-10-30 | 10:00 | 72.36 | 37 | 0.00 |
| 2003-10-30 | 11:00 | 75.02 | 35 | 0.00 |
| 2003-10-30 | 12:00 | 76.33 | 32 | 0.00 |
| 2003-10-30 | 13:00 | 77.61 | 31 | 0.00 |
| 2003-10-30 | 14:00 | 78.33 | 29 | 0.00 |
| 2003-10-30 | 15:00 | 79.23 | 28 | 0.00 |
| 2003-10-30 | 16:00 | 78.40 | 30 | 0.00 |
| 2003-10-30 | 17:00 | 77.59 | 30 | 0.00 |
| 2003-10-30 | 18:00 | 75.43 | 33 | 0.00 |
| 2003-10-30 | 19:00 | 73.13 | 36 | 0.00 |
| 2003-10-30 | 20:00 | 71.42 | 38 | 0.00 |
| 2003-10-30 | 21:00 | 68.74 | 43 | 0.00 |
| 2003-10-30 | 22:00 | 65.79 | 47 | 0.00 |
| 2003-10-30 | 23:00 | 65.30 | 47 | 0.00 |
| 2003-10-30 | 24:00 | 63.59 | 49 | 0.00 |

## TABLE B-1 (CONT'D)

| Date | Time HH:MM | Temperature °F | R/H % | Total Precipitation (in.) |
|---|---|---|---|---|
| 2003-10-31 | 1:00 | 62.06 | 51 | 0.00 |
| 2003-10-31 | 2:00 | 60.78 | 53 | 0.00 |
| 2003-10-31 | 3:00 | 60.62 | 53 | 0.00 |
| 2003-10-31 | 4:00 | 60.85 | 53 | 0.00 |
| 2003-10-31 | 5:00 | 59.92 | 54 | 0.00 |
| 2003-10-31 | 6:00 | 59.92 | 54 | 0.00 |
| 2003-10-31 | 7:00 | 58.26 | 56 | 0.00 |
| 2003-10-31 | 8:00 | 57.60 | 57 | 0.00 |
| 2003-10-31 | 9:00 | 63.91 | 47 | 0.00 |
| 2003-10-31 | 10:00 | 65.59 | 42 | 0.00 |
| 2003-10-31 | 11:00 | 67.21 | 40 | 0.00 |
| 2003-10-31 | 12:00 | 68.72 | 38 | 0.00 |
| 2003-10-31 | 13:00 | 71.01 | 35 | 0.00 |
| 2003-10-31 | 14:00 | 72.16 | 34 | 0.00 |
| 2003-10-31 | 15:00 | 73.31 | 33 | 0.00 |
| 2003-10-31 | 16:00 | 73.00 | 32 | 0.00 |
| 2003-10-31 | 17:00 | 71.80 | 33 | 0.00 |
| 2003-10-31 | 18:00 | 69.76 | 34 | 0.00 |
| 2003-10-31 | 19:00 | 67.69 | 35 | 0.00 |
| 2003-10-31 | 20:00 | 65.88 | 36 | 0.00 |
| 2003-10-31 | 21:00 | 64.65 | 38 | 0.00 |
| 2003-10-31 | 22:00 | 64.20 | 38 | 0.00 |
| 2003-10-31 | 23:00 | 64.45 | 37 | 0.00 |
| 2003-10-31 | 24:00 | 64.53 | 37 | 0.00 |
| 2003-11-01 | 1:00 | 63.45 | 39 | 0.00 |
| 2003-11-01 | 2:00 | 62.69 | 41 | 0.00 |
| 2003-11-01 | 3:00 | 62.22 | 43 | 0.00 |
| 2003-11-01 | 4:00 | 62.06 | 42 | 0.00 |
| 2003-11-01 | 5:00 | 60.67 | 43 | 0.00 |
| 2003-11-01 | 6:00 | 61.30 | 42 | 0.00 |
| 2003-11-01 | 7:00 | 60.64 | 43 | 0.00 |
| 2003-11-01 | 8:00 | 60.49 | 43 | 0.00 |
| 2003-11-01 | 9:00 | 63.10 | 39 | 0.00 |
| 2003-11-01 | 10:00 | 66.65 | 33 | 0.00 |
| 2003-11-01 | 11:00 | 69.15 | 31 | 0.00 |
| 2003-11-01 | 12:00 | 69.91 | 31 | 0.00 |
| 2003-11-01 | 13:00 | 70.99 | 31 | 0.00 |
| 2003-11-01 | 14:00 | 73.85 | 30 | 0.00 |

## TABLE B-1 (CONT'D)

| Date | Time HH:MM | Temperature °F | R/H % | Total Precipitation (in.) |
|---|---|---|---|---|
| 2003-11-01 | 15:00 | 74.55 | 28 | 0.00 |
| 2003-11-01 | 16:00 | 74.70 | 27 | 0.00 |
| 2003-11-01 | 17:00 | 74.12 | 29 | 0.00 |
| 2003-11-01 | 18:00 | 72.10 | 33 | 0.00 |
| 2003-11-01 | 19:00 | 69.60 | 35 | 0.00 |
| 2003-11-01 | 20:00 | 66.65 | 39 | 0.00 |
| 2003-11-01 | 21:00 | 64.90 | 42 | 0.00 |
| 2003-11-01 | 22:00 | 63.64 | 43 | 0.00 |
| 2003-11-01 | 23:00 | 63.10 | 44 | 0.00 |
| 2003-11-01 | 24:00 | 60.35 | 46 | 0.00 |
| 2003-11-02 | 1:00 | 59.90 | 47 | 0.00 |
| 2003-11-02 | 2:00 | 59.92 | 46 | 0.00 |
| 2003-11-02 | 3:00 | 59.68 | 46 | 0.00 |
| 2003-11-02 | 4:00 | 57.36 | 49 | 0.00 |
| 2003-11-02 | 5:00 | 56.98 | 49 | 0.00 |
| 2003-11-02 | 6:00 | 54.25 | 49 | 0.00 |
| 2003-11-02 | 7:00 | 52.99 | 52 | 0.00 |
| 2003-11-02 | 8:00 | 57.04 | 47 | 0.00 |
| 2003-11-02 | 9:00 | 62.78 | 44 | 0.00 |
| 2003-11-02 | 10:00 | 65.44 | 40 | 0.00 |
| 2003-11-02 | 11:00 | 68.85 | 36 | 0.00 |
| 2003-11-02 | 12:00 | 70.00 | 34 | 0.00 |
| 2003-11-02 | 13:00 | 71.44 | 31 | 0.00 |
| 2003-11-02 | 14:00 | 70.09 | 33 | 0.00 |
| 2003-11-02 | 15:00 | 68.68 | 34 | 0.00 |
| 2003-11-02 | 16:00 | 67.78 | 34 | 0.00 |
| 2003-11-02 | 17:00 | 67.75 | 33 | 0.00 |
| 2003-11-02 | 18:00 | 66.63 | 33 | 0.00 |
| 2003-11-02 | 19:00 | 65.21 | 33 | 0.00 |
| 2003-11-02 | 20:00 | 64.58 | 33 | 0.00 |
| 2003-11-02 | 21:00 | 63.39 | 36 | 0.00 |
| 2003-11-02 | 22:00 | 61.77 | 42 | 0.00 |
| 2003-11-02 | 23:00 | 60.31 | 45 | 0.00 |
| 2003-11-02 | 24:00 | 58.93 | 48 | 0.00 |
| 2003-11-03 | 1:00 | 58.57 | 44 | 0.00 |
| 2003-11-03 | 2:00 | 57.04 | 45 | 0.00 |
| 2003-11-03 | 3:00 | 56.30 | 45 | 0.00 |
| 2003-11-03 | 4:00 | 53.82 | 49 | 0.00 |
| 2003-11-03 | 5:00 | 54.32 | 48 | 0.00 |

## TABLE B-1 (CONT'D)

| Date | Time HH:MM | Temperature °F | R/H % | Total Precipitation (in.) |
|---|---|---|---|---|
| 2003-11-03 | 6:00 | 53.62 | 48 | 0.00 |
| 2003-11-03 | 7:00 | 53.69 | 47 | 0.00 |
| 2003-11-03 | 8:00 | 55.26 | 44 | 0.00 |
| 2003-11-03 | 9:00 | 58.17 | 41 | 0.00 |
| 2003-11-03 | 10:00 | 61.61 | 35 | 0.00 |
| 2003-11-03 | 11:00 | 64.69 | 32 | 0.00 |
| 2003-11-03 | 12:00 | 65.41 | 32 | 0.00 |
| 2003-11-03 | 13:00 | 66.27 | 32 | 0.00 |
| 2003-11-03 | 14:00 | 67.33 | 29 | 0.00 |
| 2003-11-03 | 15:00 | 68.25 | 28 | 0.00 |
| 2003-11-03 | 16:00 | 68.13 | 27 | 0.00 |
| 2003-11-03 | 17:00 | 67.46 | 27 | 0.00 |
| 2003-11-03 | 18:00 | 65.91 | 30 | 0.00 |
| 2003-11-03 | 19:00 | 63.72 | 33 | 0.00 |
| 2003-11-03 | 20:00 | 62.13 | 34 | 0.00 |
| 2003-11-03 | 21:00 | 60.15 | 37 | 0.00 |
| 2003-11-03 | 22:00 | 59.52 | 39 | 0.00 |
| 2003-11-03 | 23:00 | 56.79 | 44 | 0.00 |
| 2003-11-03 | 24:00 | 56.91 | 47 | 0.00 |
| 2003-11-04 | 1:00 | 54.28 | 51 | 0.00 |
| 2003-11-04 | 2:00 | 55.49 | 53 | 0.00 |
| 2003-11-04 | 3:00 | 52.99 | 56 | 0.00 |
| 2003-11-04 | 4:00 | 50.79 | 62 | 0.00 |
| 2003-11-04 | 5:00 | 52.66 | 63 | 0.00 |
| 2003-11-04 | 6:00 | 51.39 | 66 | 0.00 |
| 2003-11-04 | 7:00 | 47.80 | 67 | 0.00 |
| 2003-11-04 | 8:00 | 51.37 | 62 | 0.00 |
| 2003-11-04 | 9:00 | 57.65 | 55 | 0.00 |
| 2003-11-04 | 10:00 | 60.62 | 48 | 0.00 |
| 2003-11-04 | 11:00 | 63.50 | 38 | 0.00 |
| 2003-11-04 | 12:00 | 65.64 | 33 | 0.00 |
| 2003-11-04 | 13:00 | 66.88 | 31 | 0.00 |
| 2003-11-04 | 14:00 | 67.57 | 29 | 0.00 |
| 2003-11-04 | 15:00 | 69.42 | 26 | 0.00 |
| 2003-11-04 | 16:00 | 69.31 | 27 | 0.00 |
| 2003-11-04 | 17:00 | 68.83 | 27 | 0.00 |
| 2003-11-04 | 18:00 | 66.58 | 33 | 0.00 |
| 2003-11-04 | 19:00 | 64.29 | 35 | 0.00 |
| 2003-11-04 | 20:00 | 62.31 | 37 | 0.00 |

## TABLE B-1 (CONT'D)

| Date | Time HH:MM | Temperature °F | R/H % | Total Precipitation (in.) |
|---|---|---|---|---|
| 2003-11-04 | 21:00 | 59.70 | 41 | 0.00 |
| 2003-11-04 | 22:00 | 57.22 | 42 | 0.00 |
| 2003-11-04 | 23:00 | 53.87 | 43 | 0.00 |
| 2003-11-04 | 24:00 | 52.23 | 45 | 0.00 |
| 2003-11-05 | 1:00 | 50.90 | 47 | 0.00 |
| 2003-11-05 | 2:00 | 49.35 | 47 | 0.00 |
| 2003-11-05 | 3:00 | 48.38 | 51 | 0.00 |
| 2003-11-05 | 4:00 | 46.58 | 48 | 0.00 |
| 2003-11-05 | 5:00 | 45.10 | 48 | 0.00 |
| 2003-11-05 | 6:00 | 44.98 | 51 | 0.00 |
| 2003-11-05 | 7:00 | 46.62 | 52 | 0.00 |
| 2003-11-05 | 8:00 | 49.50 | 51 | 0.00 |
| 2003-11-05 | 9:00 | 57.15 | 42 | 0.00 |
| 2003-11-05 | 10:00 | 64.33 | 31 | 0.00 |
| 2003-11-05 | 11:00 | 66.29 | 29 | 0.00 |
| 2003-11-05 | 12:00 | 69.53 | 26 | 0.00 |
| 2003-11-05 | 13:00 | 70.09 | 25 | 0.00 |
| 2003-11-05 | 14:00 | 71.82 | 23 | 0.00 |
| 2003-11-05 | 15:00 | 73.11 | 21 | 0.00 |
| 2003-11-05 | 16:00 | 73.65 | 20 | 0.00 |
| 2003-11-05 | 17:00 | 72.68 | 20 | 0.00 |
| 2003-11-05 | 18:00 | 70.14 | 21 | 0.00 |
| 2003-11-05 | 19:00 | 67.89 | 22 | 0.00 |
| 2003-11-05 | 20:00 | 64.02 | 25 | 0.00 |
| 2003-11-05 | 21:00 | 63.01 | 26 | 0.00 |
| 2003-11-05 | 22:00 | 60.13 | 29 | 0.00 |
| 2003-11-05 | 23:00 | 57.81 | 30 | 0.00 |
| 2003-11-05 | 24:00 | 53.87 | 30 | 0.00 |
| 2003-11-06 | 1:00 | 52.18 | 32 | 0.00 |
| 2003-11-06 | 2:00 | 52.03 | 34 | 0.00 |
| 2003-11-06 | 3:00 | 50.58 | 35 | 0.00 |
| 2003-11-06 | 4:00 | 48.34 | 37 | 0.00 |
| 2003-11-06 | 5:00 | 48.85 | 39 | 0.00 |
| 2003-11-06 | 6:00 | 47.93 | 40 | 0.00 |
| 2003-11-06 | 7:00 | 47.73 | 44 | 0.00 |
| 2003-11-06 | 8:00 | 53.42 | 38 | 0.00 |
| 2003-11-06 | 9:00 | 61.84 | 29 | 0.00 |
| 2003-11-06 | 10:00 | 64.06 | 27 | 0.00 |
| 2003-11-06 | 11:00 | 69.28 | 23 | 0.00 |

## TABLE B-1 (CONT'D)

| Date | Time HH:MM | Temperature °F | R/H % | Total Precipitation (in.) |
|---|---|---|---|---|
| 2003-11-06 | 12:00 | 70.75 | 22 | 0.00 |
| 2003-11-06 | 13:00 | 72.32 | 21 | 0.00 |
| 2003-11-06 | 14:00 | 74.43 | 19 | 0.00 |
| 2003-11-06 | 15:00 | 74.03 | 19 | 0.00 |
| 2003-11-06 | 16:00 | 75.04 | 18 | 0.00 |
| 2003-11-06 | 17:00 | 74.39 | 18 | 0.00 |
| 2003-11-06 | 18:00 | 71.56 | 20 | 0.00 |
| 2003-11-06 | 19:00 | 68.04 | 22 | 0.00 |
| 2003-11-06 | 20:00 | 64.33 | 24 | 0.00 |
| 2003-11-06 | 21:00 | 62.60 | 25 | 0.00 |
| 2003-11-06 | 22:00 | 60.35 | 27 | 0.00 |
| 2003-11-06 | 23:00 | 61.30 | 26 | 0.00 |
| 2003-11-06 | 24:00 | 56.84 | 29 | 0.00 |

# APPENDIX C. SOIL MOISTURE LOGS

| Date | Time | CALIBRATION AREA (%) | | | | | Time | MOGUL AREA (%) | | | | | Time | EXTREME AREA (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 - 6" | 6 -12" | 12-24" | 24-36" | 36-48" | | 0 - 6" | 6 -12" | 12-24" | 24-36" | 36-48" | | 0 - 6" | 6 -12" | 12-24" | 24-36" | 36-48" |
| 10/28/2003 | 955 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 1004 | 1.7 | 2.0 | 3.5 | 4.0 | 4.1 | 1013 | 1.6 | 2.1 | 3.4 | 4.0 | 4.2 |
| | 1405 | 1.8 | 2.2 | 3.7 | 3.6 | 4.0 | 1413 | 1.7 | 2.0 | 3.5 | 4.0 | 4.1 | 1420 | 1.6 | 2.1 | 3.4 | 4.0 | 4.1 |
| | | | | | | | | | | | | | | | | | | |
| 10/29/2003 | 705 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 713 | 1.7 | 2.0 | 3.6 | 3.9 | 4.0 | 719 | 1.6 | 2.1 | 3.4 | 4.0 | 4.1 |
| | 1300 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 1310 | 1.7 | 2.0 | 3.6 | 3.9 | 4.0 | 1318 | 1.6 | 2.1 | 3.4 | 4.0 | 4.1 |
| | | | | | | | | | | | | | | | | | | |
| 10/30/2003 | 730 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 738 | 1.7 | 2.0 | 3.5 | 3.9 | 4.0 | 745 | 1.6 | 2.1 | 3.4 | 4.0 | 4.2 |
| | 1502 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 1513 | 1.8 | 2.0 | 3.6 | 4.0 | 4.1 | 1518 | 1.6 | 2.1 | 3.4 | 4.0 | 4.1 |
| | | | | | | | | | | | | | | | | | | |
| 10/31/2003 | 651 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 703 | 1.6 | 2.0 | 3.5 | 3.9 | 4.0 | 712 | 1.6 | 2.1 | 3.4 | 4.0 | 4.2 |
| | 1422 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 1434 | 1.7 | 2.0 | 3.6 | 3.9 | 4.1 | 1444 | 1.6 | 2.1 | 3.4 | 3.9 | 4.1 |
| | | | | | | | | | | | | | | | | | | |
| 11/3/2003 | 650 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 659 | 1.7 | 2.0 | 3.6 | 3.9 | 4.0 | 707 | 1.6 | 2.1 | 3.4 | 3.9 | 4.1 |
| | 1400 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 1408 | 1.7 | 2.0 | 3.6 | 3.9 | 4.0 | 1419 | 1.6 | 2.1 | 3.4 | 3.9 | 4.1 |
| | | | | | | | | | | | | | | | | | | |
| 11/4/2003 | 635 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 643 | 1.7 | 2.0 | 3.6 | 3.9 | 4.1 | 650 | 1.6 | 2.1 | 3.4 | 3.9 | 4.1 |
| | 1340 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 1348 | 1.7 | 2.0 | 3.5 | 3.9 | 4.1 | 1357 | 1.6 | 2.1 | 3.4 | 3.9 | 4.1 |
| | | | | | | | | | | | | | | | | | | |
| 11/5/2003 | 645 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 653 | 1.7 | 2.0 | 3.5 | 3.9 | 4.0 | 701 | 1.6 | 2.1 | 3.4 | 3.9 | 4.1 |
| | 1420 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 1429 | 1.7 | 2.0 | 3.6 | 3.9 | 4.0 | 1438 | 1.6 | 2.1 | 3.4 | 3.9 | 4.1 |
| | | | | | | | | | | | | | | | | | | |
| 11/6/2003 | 640 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 648 | 1.7 | 2.0 | 3.5 | 3.9 | 4.0 | 657 | 1.6 | 2.0 | 3.4 | 3.9 | 4.1 |
| | 1400 | 1.8 | 2.3 | 3.7 | 3.6 | 4.0 | 1408 | 1.7 | 2.0 | 3.5 | 3.9 | 4.0 | 1415 | 1.6 | 2.0 | 3.4 | 3.9 | 4.1 |

# APPENDIX D. DAILY ACTIVITY LOG

| Date | No. of People | Area Tested | Status Start Time | Status Stop Time | Duration, min | Operational Status | Operational Status-Comments | Track Method | Pattern | Field Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20031028 | 2 | INITIAL SET UP | 930 | 1110 | 100 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | HOT | DRY |
| 20031028 | 1 | BLIND TEST GRID | 1110 | 1125 | 15 | COLLECTING DATA | SIX LANE CALIBRATION WITH BOLTS | GPS | LINER | HOT | DRY |
| 20031028 | 1 | BLIND TEST GRID | 1125 | 1207 | 42 | COLLECTING DATA | RUNNING BTG NORTH /SOUTH | GPS | LINER | HOT | DRY |
| 20031028 | 2 | BLIND TEST GRID | 1207 | 1220 | 13 | DOWNTIME DUE TO EQUIP MAINT/CHECK | CHECKING/DOWNLOADING DATA | NA | NA | HOT | DRY |
| 20031028 | 1 | CALIBRATION LANE | 1220 | 1240 | 20 | COLLECTING DATA | RUNNING CALIBRATION LANE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031028 | 2 | CALIBRATION LANE | 1240 | 1247 | 7 | DOWNTIME DUE TO EQUIP MAINT/CHECK | COULD NOT GET A FIX ON GPS | NA | NA | HOT | DRY |
| 20031028 | 1 | CALIBRATION LANE | 1247 | 1319 | 32 | COLLECTING DATA | RUNNING CALIBRATION LANE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031028 | 2 | CALIBRATION LANE | 1319 | 1330 | 11 | DOWNTIME DUE TO EQUIP MAINT/CHECK | CHECKING/DOWNLOADING DATA | NA | NA | HOT | DRY |
| 20031028 | 2 | CALIBRATION LANE | 1330 | 1335 | 5 | DOWNTIME DUE TO EQUIP MAINT/CHECK | REPLACED BATTERY | NA | NA | HOT | DRY |
| 20031028 | 2 | OPEN RANGE | 1335 | 1415 | 40 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | HOT | DRY |
| 20031028 | 1 | OPEN RANGE | 1415 | 1545 | 90 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |

Note: Activities pertinent to this specific demonstration are indicated in highlighted text.

| Date | No. of People | Area Tested | Status Start Time | Status Stop Time | Duration, min | Operational Status | Operational Status-Comments | Track Method | Pattern | Field Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20031028 | 1 | OPEN RANGE | 1545 | 1601 | 16 | BREAK/LUNCH | BREAK | NA | NA | HOT | DRY |
| 20031028 | 1 | OPEN RANGE | 1601 | 1646 | 45 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031028 | 2 | OPEN RANGE | 1646 | 1700 | 14 | SET-UP/ MOBILIZATION | EQUIPMENT BREAKDOWN EOD | NA | NA | HOT | DRY |
| 20031029 | 2 | OPEN RANGE | 655 | 856 | 121 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | HOT | DRY |
| 20031029 | 1 | OPEN RANGE | 856 | 900 | 4 | COLLECTING DATA | SIX LANE CALIBRATION WITH BOLTS | GPS | LINER | HOT | DRY |
| 20031029 | 2 | OPEN RANGE | 900 | 910 | 10 | SET-UP/MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | HOT | DRY |
| 20031029 | 1 | OPEN RANGE | 910 | 1130 | 140 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031029 | 1 | OPEN RANGE | 1130 | 1135 | 5 | DOWNTIME DUE TO EQUIP MAINT/CHECK | REPLACED BATTERY | NA | NA | HOT | DRY |
| 20031029 | 1 | OPEN RANGE | 1135 | 1158 | 13 | BREAK/LUNCH | BREAK | NA | NA | HOT | DRY |
| 20031029 | 1 | OPEN RANGE | 1158 | 1342 | 104 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031029 | 1 | OPEN RANGE | 1342 | 1406 | 24 | BREAK/LUNCH | BREAK | NA | NA | HOT | DRY |
| 20031029 | 1 | OPEN RANGE | 1406 | 1410 | 4 | DOWNTIME DUE TO EQUIP MAINT/CHECK | REPLACED BATTERY | NA | NA | HOT | DRY |

| Date | No. of People | Area Tested | Status Start Time | Status Stop Time | Duration, min | Operational Status | Operational Status-Comments | Track Method | Pattern | Field Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20031029 | 1 | OPEN RANGE | 1410 | 1500 | 50 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031029 | 1 | OPEN RANGE | 1500 | 1515 | 15 | DOWNTIME DUE TO EQUIP MAINT/CHECK | MEMORY DISK FULL | NA | NA | HOT | DRY |
| 20031029 | 1 | OPEN RANGE | 1515 | 1528 | 13 | BREAK/LUNCH | BREAK | NA | NA | HOT | DRY |
| 20031029 | 1 | OPEN RANGE | 1528 | 1613 | 45 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031029 | 2 | OPEN RANGE | 1613 | 1640 | 27 | SET-UP/ MOBILIZATION | EQUIPMENT BREAKDOWN EOD | NA | NA | HOT | DRY |
| 20031030 | 2 | OPEN RANGE | 650 | 730 | 40 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | HOT | DRY |
| 20031030 | 2 | OPEN RANGE | 730 | 735 | 5 | COLLECTING DATA | SIX LANE CALIBRATION WITH BOLTS | GPS | LINER | HOT | DRY |
| 20031030 | 2 | OPEN RANGE | 735 | 745 | 10 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | HOT | DRY |
| 20031030 | 2 | OPEN RANGE | 745 | 1015 | 150 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031030 | 2 | OPEN RANGE | 1015 | 1055 | 40 | SET-UP/MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | HOT | DRY |
| 20031030 | 2 | OPEN RANGE | 1055 | 1105 | 10 | BREAK/LUNCH | BREAK | NA | NA | HOT | DRY |
| 20031030 | 2 | OPEN RANGE | 1105 | 1225 | 80 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |

| Date | No. of People | Area Tested | Status Start Time | Status Stop Time | Duration, min | Operational Status | Operational Status-Comments | Track Method | Pattern | Field Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20031030 | 2 | OPEN RANGE | 1225 | 1229 | 4 | DOWNTIME DUE TO EQUIP MAINT/CHECK | REPLACED BATTERY | NA | NA | HOT | DRY |
| 20031030 | 2 | OPEN RANGE | 1229 | 1320 | 51 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031030 | 2 | OPEN RANGE | 1320 | 1335 | 15 | DOWNTIME DUE TO EQUIP MAINT/CHECK | MEMORY DISK FULL | NA | NA | HOT | DRY |
| 20031030 | 2 | OPEN RANGE | 1335 | 1425 | 50 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031030 | 2 | OPEN RANGE | 1425 | 1429 | 4 | DOWNTIME DUE TO EQUIP MAINT/CHECK | REPLACED BATTERY | NA | NA | HOT | DRY |
| 20031030 | 2 | OPEN RANGE | 1429 | 1440 | 11 | DOWNTIME DUE TO EQUIP MAINT/CHECK | CHECKING/ DOWNLOADING DATA | NA | NA | HOT | DRY |
| 20031030 | 2 | OPEN RANGE | 1440 | 1535 | 55 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/ SOUTH | GPS | LINER | HOT | DRY |
| 20031030 | 2 | OPEN RANGE | 1535 | 1645 | 70 | SET-UP/ MOBILIZATION | EQUIPMENT BREAKDOWN EOD | NA | NA | HOT | DRY |
| 20031031 | 2 | OPEN RANGE | 645 | 1118 | 273 | DOWNTIME DUE TO EQUIPMENT FAILURE | SOFTWARE PROBLEM | NA | NA | HOT | DRY |
| 20031031 | 2 | OPEN RANGE | 1118 | 1142 | 24 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | HOT | DRY |
| 20031031 | 2 | OPEN RANGE | 1142 | 1335 | 113 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031031 | 2 | OPEN RANGE | 1335 | 1344 | 9 | DOWNTIME DUE TO EQUIP MAINT/CHECK | REPLACED BATTERY | NA | NA | HOT | DRY |

| Date | No. of People | Area Tested | Status Start Time | Status Stop Time | Duration, min | Operational Status | Operational Status-Comments | Track Method | Pattern | Field Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20031031 | 2 | OPEN RANGE | 1344 | 1517 | 93 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031031 | 2 | OPEN RANGE | 1517 | 1525 | 8 | DOWNTIME DUE TO EQUIP MAINT/CHECK | REPLACED BATTERY | NA | NA | HOT | DRY |
| 20031031 | 2 | OPEN RANGE | 1525 | 1534 | 9 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031031 | 2 | OPEN RANGE | 1534 | 1539 | 5 | DOWNTIME DUE TO EQUIP MAINT/CHECK | CHECKING/ DOWNLOADING DATA | NA | NA | HOT | DRY |
| 20031031 | 2 | OPEN RANGE | 1539 | 1638 | 59 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031031 | 2 | OPEN RANGE | 1638 | 1645 | 7 | SET-UP/ MOBILIZATION | EQUIPMENT BREAKDOWN EOD | NA | NA | HOT | DRY |
| 20031103 | 2 | YUMA EXTREME | 625 | 705 | 40 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | COOL | DRY |
| 20031103 | 2 | YUMA EXTREME | 705 | 708 | 3 | COLLECTING DATA | SIX LANE CALIBRATION WITH BOLTS | GPS | LINER | COOL | DRY |
| 20031103 | 2 | YUMA EXTREME | 708 | 800 | 52 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | COOL | DRY |
| 20031103 | 2 | YUMA EXTREME | 800 | 1030 | 150 | COLLECTING DATA | RUNNING YUMA EXTREME NORTH/SOUTH | GPS | LINER | COOL | DRY |
| 20031103 | 2 | YUMA EXTREME | 1030 | 1035 | 5 | DOWNTIME DUE TO EQUIP MAINT/CHECK | SWAPPED OUT BATTERY | NA | NA | COOL | DRY |
| 20031103 | 2 | YUMA EXTREME | 1035 | 1105 | 30 | BREAK/LUNCH | BREAK | NA | NA | COOL | DRY |

| Date | No. of People | Area Tested | Status Start Time | Status Stop Time | Duration, min | Operational Status | Operational Status-Comments | Track Method | Pattern | Field Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20031103 | 2 | YUMA EXTREME | 1105 | 1339 | 154 | COLLECTING DATA | RUNNING YUMA EXTREME NORTH/SOUTH | GPS | LINER | COOL | DRY |
| 20031103 | 2 | YUMA EXTREME | 1339 | 1344 | 5 | DOWNTIME DUE TO EQUIP MAINT/CHECK | REPLACED BATTERY | NA | NA | COOL | DRY |
| 20031103 | 2 | YUMA EXTREME | 1344 | 1408 | 24 | BREAK/LUNCH | LUNCH | NA | NA | COOL | DRY |
| 20031103 | 2 | YUMA EXTREME | 1408 | 1600 | 112 | COLLECTING DATA | RUNNING YUMA EXTREME NORTH/SOUTH | GPS | LINER | COOL | DRY |
| 20031103 | 2 | YUMA EXTREME | 1600 | 1635 | 35 | SET-UP/ MOBILIZATION | EQUIPMENT BREAKDOWN EOD | NA | NA | COOL | DRY |
| 20031104 | 2 | MOGUL AREA | 630 | 650 | 20 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | COOL | DRY |
| 20031104 | 2 | MOGUL AREA | 650 | 657 | 7 | COLLECTING DATA | SIX LANE CALIBRATION WITH BOLTS | GPS | LINER | COOL | DRY |
| 20031104 | 2 | MOGUL AREA | 657 | 725 | 28 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | COOL | DRY |
| 20031104 | 2 | MOGUL AREA | 725 | 950 | 145 | COLLECTING DATA | RUNNING MOGUL AREA NORTH/SOUTH | GPS | LINER | COOL | DRY |
| 20031104 | 2 | MOGUL AREA | 950 | 955 | 5 | DOWNTIME DUE TO EQUIP MAINT/CHECK | SWAPPED OUT BATTERY | NA | NA | COOL | DRY |
| 20031104 | 2 | MOGUL AREA | 955 | 1016 | 21 | BREAK/LUNCH | BREAK | NA | NA | COOL | DRY |
| 20031104 | 2 | MOGUL AREA | 1016 | 1120 | 64 | COLLECTING DATA | RUNNING MOGUL AREA NORTH/SOUTH | GPS | LINER | COOL | DRY |

| Date | No. of People | Area Tested | Status Start Time | Status Stop Time | Duration, min | Operational Status | Operational Status-Comments | Track Method | Pattern | Field Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20031104 | 2 | MOGUL AREA | 1120 | 1255 | 95 | COLLECTING DATA | RUNNING MOGUL AREA EAST/WEST | GPS | LINER | COOL | DRY |
| 20031104 | 2 | MOGUL AREA | 1255 | 1300 | 5 | DOWNTIME DUE TO EQUIP MAINT/CHECK | REPLACED BATTERY | NA | NA | COOL | DRY |
| 20031104 | 2 | MOGUL AREA | 1300 | 1330 | 30 | DOWNTIME DUE TO EQUIP MAINT/CHECK | CHECKING/DOWNLOADING DATA | NA | NA | COOL | DRY |
| 20031104 | 2 | MOGUL AREA | 1330 | 1400 | 30 | BREAK/LUNCH | LUNCH | NA | NA | COOL | DRY |
| 20031104 | 2 | CALIBRATION LANE | 1400 | 1450 | 50 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | COOL | DRY |
| 20031104 | 2 | CALIBRATION LANE | 1450 | 1542 | 52 | COLLECTING DATA | RUNNING CALIBRATION LANE EAST/WEST | GPS | LINER | COOL | DRY |
| 20031104 | 2 | CALIBRATION LANE | 1542 | 1620 | 38 | SET-UP/ MOBILIZATION | EQUIPMENT BREAKDOWN EOD | NA | NA | COOL | DRY |
| 20031105 | 2 | OPEN RANGE | 635 | 700 | 25 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | COOL | DRY |
| 20031105 | 2 | OPEN RANGE | 700 | 709 | 9 | COLLECTING DATA | SIX LANE CALIBRATION WITH BOLTS | GPS | LINER | COOL | DRY |
| 20031105 | 2 | OPEN RANGE | 709 | 720 | 11 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | COOL | DRY |
| 20031105 | 2 | OPEN RANGE | 720 | 933 | 133 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | COOL | DRY |
| 20031105 | 2 | OPEN RANGE | 933 | 938 | 5 | DOWNTIME DUE TO EQUIP MAINT/CHECK | REPLACED BATTERY | NA | NA | COOL | DRY |

| Date | No. of People | Area Tested | Status Start Time | Status Stop Time | Duration, min | Operational Status | Operational Status-Comments | Track Method | Pattern | Field Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20031105 | 2 | OPEN RANGE | 938 | 1000 | 22 | BREAK/LUNCH | BREAK | NA | NA | COOL | DRY |
| 20031105 | 2 | OPEN RANGE | 1000 | 1041 | 41 | SET-UP /MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | COOL | DRY |
| 20031105 | 2 | OPEN RANGE | 1041 | 1051 | 10 | COLLECTING DATA | SIX LANE CALIBRATION WITH BOLTS | GPS | LINER | COOL | DRY |
| 20031105 | 2 | OPEN RANGE | 1051 | 1155 | 64 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031105 | 2 | OPEN RANGE | 1155 | 1220 | 25 | DOWNTIME DUE TO EQUIP MAINT/CHECK | CHECKING/DOWNLOADING DATA | NA | NA | HOT | DRY |
| 20031105 | 2 | OPEN RANGE | 1220 | 1310 | 50 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | HOT | DRY |
| 20031105 | 2 | OPEN RANGE | 1310 | 1440 | 90 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031105 | 2 | OPEN RANGE | 1440 | 1515 | 35 | DOWNTIME DUE TO EQUIP MAINT/CHECK | CHECKING/DOWNLOADING DATA | NA | NA | HOT | DRY |
| 20031105 | 2 | YUMA EXTREME | 1515 | 1520 | 5 | SET-UP/MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | HOT | DRY |
| 20031105 | 2 | YUMA EXTREME | 1520 | 1612 | 52 | COLLECTING DATA | RUNNING YUMA EXTREME NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031105 | 2 | YUMA EXTREME | 1612 | 1625 | 13 | SET-UP/ MOBILIZATION | EQUIPMENT BREAKDOWN EOD | NA | NA | HOT | DRY |
| 20031106 | 2 | OPEN RANGE | 630 | 645 | 15 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | COOL | DRY |

| Date | No. of People | Area Tested | Status Start Time | Status Stop Time | Duration, min | Operational Status | Operational Status-Comments | Track Method | Pattern | Field Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20031106 | 2 | OPEN RANGE | 645 | 650 | 5 | COLLECTING DATA | SIX LANE CALIBRATION WITH BOLTS | GPS | LINER | COOL | DRY |
| 20031106 | 2 | OPEN RANGE | 650 | 730 | 40 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | COOL | DRY |
| 20031106 | 2 | OPEN RANGE | 730 | 920 | 110 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | NA | COOL | DRY |
| 20031106 | 2 | OPEN RANGE | 920 | 956 | 36 | BREAK/LUNCH | BREAK | NA | NA | COOL | DRY |
| 20031106 | 2 | CALIBRATION PIT | 956 | 1037 | 41 | SET-UP/MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | COOL | DRY |
| 20031106 | 2 | CALIBRATION PIT | 1037 | 1102 | 25 | COLLECTING DATA | RUNNING SIGNATURE DATA NORTH/SOUTH ON 155 MM | GPS | LINER | HOT | DRY |
| 20031106 | 2 | CALIBRATION PIT | 1102 | 1109 | 7 | COLLECTING DATA | RUNNING SIGNATURE DATA NORTH/SOUTH ON ATC 105 MM | GPS | LINER | HOT | DRY |
| 20031106 | 2 | CALIBRATION PIT | 1109 | 1115 | 6 | COLLECTING DATA | RUNNING SIGNATURE DATA NORTH/SOUTH ON 105 MM | GPS | LINER | HOT | DRY |
| 20031106 | 2 | CALIBRATION PIT | 1115 | 1120 | 5 | COLLECTING DATA | RUNNING SIGNATURE DATA NORTH/SOUTH ON 81 MM | GPS | LINER | HOT | DRY |
| 20031106 | 2 | CALIBRATION PIT | 1120 | 1125 | 5 | COLLECTING DATA | RUNNING SIGNATURE DATA NORTH/SOUTH ON 2.75 INCH | GPS | LINER | HOT | DRY |
| 20031106 | 2 | CALIBRATION PIT | 1125 | 1135 | 10 | COLLECTING DATA | RUNNING SIGNATURE DATA NORTH/SOUTH ON MK 118 | GPS | LINER | HOT | DRY |
| 20031106 | 2 | CALIBRATION PIT | 1135 | 1141 | 6 | COLLECTING DATA | RUNNING SIGNATURE DATA NORTH/SOUTH ON 60 MM | GPS | LINER | HOT | DRY |

| Date | No. of People | Area Tested | Status Start Time | Status Stop Time | Duration, min | Operational Status | Operational Status-Comments | Track Method | Pattern | Field Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20031106 | 2 | CALIBRATION PIT | 1141 | 1148 | 7 | COLLECTING DATA | RUNNING SIGNATURE DATA NORTH/SOUTH ON 57 MM | GPS | LINER | HOT | DRY |
| 20031106 | 2 | CALIBRATION PIT | 1148 | 1156 | 8 | COLLECTING DATA | RUNNING SIGNATURE DATA NORTH/SOUTH ON BDU 28 | GPS | LINER | HOT | DRY |
| 20031106 | 2 | CALIBRATION PIT | 1156 | 1202 | 6 | COLLECTING DATA | RUNNING SIGNATURE DATA NORTH/SOUTH ON 40 MM | GPS | LINER | HOT | DRY |
| 20031106 | 2 | CALIBRATION PIT | 1202 | 1206 | 4 | COLLECTING DATA | RUNNING SIGNATURE DATA NORTH/SOUTH ON BLU-26 | GPS | LINER | HOT | DRY |
| 20031106 | 2 | CALIBRATION PIT | 1206 | 1214 | 8 | COLLECTING DATA | RUNNING SIGNATURE DATA NORTH/SOUTH ON M 42 | GPS | LINER | HOT | DRY |
| 20031106 | 2 | CALIBRATION PIT | 1214 | 1220 | 6 | COLLECTING DATA | RUNNING SIGNATURE DATA NORTH/SOUTH ON 20 MM | GPS | LINER | HOT | DRY |
| 20031106 | 2 | CALIBRATION PIT | 1220 | 1226 | 6 | COLLECTING DATA | RUNNING SIGNATURE DATA NORTH/SOUTH ON M 385 | GPS | LINER | HOT | DRY |
| 20031106 | 2 | CALIBRATION PIT | 1226 | 1310 | 44 | DOWNTIME DUE TO EQUIP MAINT/CHECK | CHECKING/DOWNLOADING DATA | NA | NA | HOT | DRY |
| 20031106 | 2 | OPEN RANGE | 1310 | 1315 | 5 | SET-UP/ MOBILIZATION | SETTING UP EQUIPMENT FOR TESTING | NA | NA | HOT | DRY |
| 20031106 | 2 | OPEN RANGE | 1315 | 1330 | 15 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031106 | 2 | OPEN RANGE | 1330 | 1347 | 17 | DOWNTIME DUE TO EQUIPMENT FAILURE | LOST GPS | NA | NA | HOT | DRY |
| 20031106 | 2 | OPEN RANGE | 1347 | 1352 | 5 | DOWNTIME DUE TO EQUIP MAINT/CHECK | SWAPPED OUT BATTERY | NA | NA | HOT | DRY |

| Date | No. of People | Area Tested | Status Start Time | Status Stop Time | Duration, min | Operational Status | Operational Status-Comments | Track Method | Pattern | Field Conditions | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20031106 | 2 | OPEN RANGE | 1352 | 1423 | 31 | COLLECTING DATA | RUNNING OPEN RANGE NORTH/SOUTH | GPS | LINER | HOT | DRY |
| 20031106 | 2 | OPEN RANGE | 1423 | 1540 | 77 | DEMOBILIZATION | END OF TEST | NA | NA | HOT | DRY |

## APPENDIX E. REFERENCES


1. Standardized UXO Technology Demonstration Site Handbook, DTC Project No. 8-CO-160-000-473, Report No. ATC-8349, March 2002.

2. Aberdeen Proving Ground Soil Survey Report, October 1998.

3. Data Summary, UXO Standardized Test Site: APG Soils Description, May 2002.

4. Yuma Proving Ground Soil Survey Report, May 2003.

5. Practical Nonparametric Statistics, W.J. Conover, John Wiley & Sons, 1980, pages 144 through 151.

## APPENDIX F. ABBREVIATIONS

| | | |
|---|---|---|
| AEC | = | U.S. Army Environmental Center |
| APG | = | Aberdeen Proving Ground |
| ATC | = | U.S. Army Aberdeen Test Center |
| CD | = | compact disc |
| CEP | = | Central Error Probability |
| DGPS | = | differential Global Positioning System |
| ERDC | = | U.S. Army Corps of Engineers Engineering Research and Development Center |
| ESTCP | = | Environmental Security Technology Certification Program |
| EQT | = | Army Environmental Quality Technology Program |
| GPS | = | Global Positioning System |
| GX | = | Geosoft executable |
| JPG | = | Jefferson Proving Ground |
| POC | = | point of contact |
| QA | = | quality assurance |
| QC | = | quality control |
| ROC | = | receiver-operating characteristic |
| RTK | = | real-time kinematic |
| SERDP | = | Strategic Environmental Research and Development Program |
| UXO | = | unexploded ordnance |
| YPG | = | U.S. Army Yuma Proving Ground |

## APPENDIX G. DISTRIBUTION LIST

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